Maryland Biological Stressor Identification Process

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List of Abbreviations

AMD	Acid Mine Drainage
ANC	Acid Neutralizing Capacity
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
LULC	Land Use Land Cover
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
MSSCS	Maryland Synoptic Stream Chemistry
mg/L	Milligrams per liter
µeq/L	Micro equivalent per liter
µS/cm	Micro Seimens per centimeter
P/G/E	Pool/Glide/Eddy
QA/QC	Quality Assurance/Quality Control
RESAC	Regional Earth Science Applications
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the 303(d) List in the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

Current Integrated Report listing categories are:

- Category 2 ("meeting some water quality standards, but with insufficient data to assess completely"), if the potential or relevant stressors were found not to be present or to have a limited association with biological integrity in the subject segments.
- Category 3 ("insufficient data to determine if any water quality standard is being attained"), if the potential or relevant stressors were identified as having insufficient data to directly link them to degrading biological conditions in the subject segments.
- Category 4c ("waterbody impairment is not caused by a pollutant"), when the only remedy for degraded biological conditions in the subject segments is a technical correction.
- Category 5 ("does not meet water quality standards"), if the potential or relevant stressors were degrading biological conditions in the subject segments.

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of Environment (MDE) biological assessment methodology assesses and lists at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that are degraded, and calculating whether they differ significantly from a reference condition watershed.

Maryland developed water quality standards to protect, maintain and improve the quality of Maryland surface waters. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. There are numerous 8-digit watersheds in Maryland that are not attaining there designated use because of biological impairments. As an indicator of designated use attainment, MDE uses Fish and Benthic Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause and source of degraded biological conditions, which will enable the Department to most effectively direct corrective management action(s).

MDE SSA generated a principal dataset after a quality assurance/quality control (QA/QC) review and vetting process of the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) round two data. Parameters were selected from the principal dataset to represent either specific “stressors” or potential “sources” of stressors. Stressors were grouped into categories representing sedimentation, habitat conditions or water chemistry.

The BSID analysis is a risk-based approach, adapted from the field of epidemiology, which estimates the strength of association between various stressors and the biological community, and the likely improvement of biology if a given stressor were removed. The assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group. The case group is defined as the sites within the assessment unit with degraded biological conditions and the controls are sites with similar physiographic characteristics that have good biological conditions. In Maryland three physiographic eco-regions were identified from the MDDNR MBSS index of biotic integrity (IBI) metrics: Highland, Eastern Piedmont, and Coastal (Southerland et al. 2005b).

Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

1. Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the 303(d) List in the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of Environment (MDE) biological assessment methodology assesses and lists at the Maryland 8-digit watershed scale (average watershed size approximately 90 sq. mi.), which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that are degraded, and calculating whether they differ significantly from a reference condition watershed (i.e., healthy stream based on reference sites determined independent of biological condition).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determines the predominant cause of reduced biological conditions, which will enable the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors and the biological community, and the likely improvement of biology if a given stressor were removed.

2. Biological Impairments

MDE's Integrated Report listing methodology incorporates indices of biological integrity (IBI) to determine attainment of the designated use of aquatic life protection. IBIs are broad, comprehensive measures of biological condition that represent numerous individual metrics which are scored based on comparison to reference conditions. An IBI score compares existing with expected conditions at sample sites using region specific baseline conditions that reflect little or no human impact. In Maryland three physiographic eco-regions were identified from the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) index of biotic integrity (IBI) metrics: Highland, Eastern Piedmont, and Coastal (Southerland et al. 2005a). The three eco-regions are identified in Figure 1.

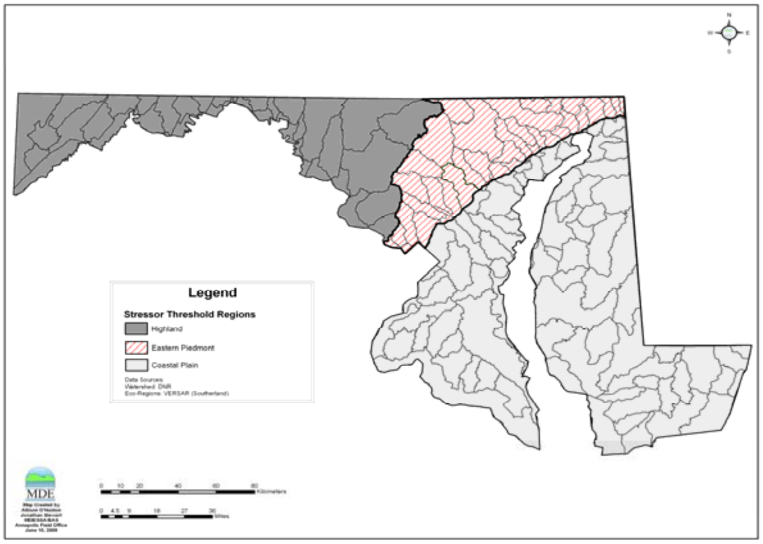

Figure 1. Eco-Region Map of Maryland

Benthic and fish IBIs (B-IBI and F-IBI, respectively) are quantitative ratings of the health of benthic macroinvertebrates and fish assemblages found at each site. Scores below the threshold value of 3 indicate poor biological conditions. Table 1 contains a more detailed description of each of the IBI categories developed.

Table 1. IBI Metrics

Narrative descriptions of stream biological integrity associated with each of the IBI categories. [a]		
Good	IBI score 4.0 - 5.0	Comparable to reference streams considered to be minimally impacted. Fall within the upper 50% of reference site conditions.
Fair	IBI score 3.0 - 3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams. Fall within the lower portion of the range of reference sites (10th to 50th percentile).
Poor	IBI score 2.0 - 2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating some degradation.
Very Poor	IBI score 1.0 - 1.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation.

a. Mercurio et al. 1999

Maryland's IBI(s) assesses biological integrity by comparing the community structure of streams to that of high quality (or reference) streams. Biological integrity is influenced by five broad factors; biological interactions, flow regime, energy source, water chemistry, and physical habitat (Karr 1991). Biological impairments could result from the influence of one or any combination of factors. All stream parameters available to diagnose the cause of biological impairments were carefully reviewed to generate the best possible representation of each factor to ensure the most comprehensive stressor identification.

Biological interactions such as competition and predation are dynamic controls for species population sizes within any community. Anthropogenic influences such as the inadvertent or intentional introduction (e.g., fish stocking) of exotic species may amplify the divergence of community structure from reference condition, thus indicate biological impairment.

The biota of aquatic systems is dependent on a recurring flow pattern including both high and low flow conditions to sustain functions such as feeding, reproduction, and dispersal. Altered flow regimes that either homogenize flow conditions (e.g., dams) or exaggerate extreme conditions (e.g., increased surface flow from impervious surface) may not provide adequate conditions to sustain populations (e.g., periodic flush of sediment from interstitial spaces, sustained current to support feeding strategy) or diversity.

Aquatic community structure reflects the mosaic of energy inputs into each stream system due to the association of organisms with unique feeding strategies. The proportion of allochthonous inputs (originating from outside the aquatic system) or autochthonous inputs (originating within the aquatic system) as well as the size of available organic materials (e.g., coarse or fine particulates) may determine which species proliferates in a community. Any modifications that could effect a change in the energy source of a system (e.g., increased nutrients, increased fine particulate organics, increased sunlight, increased temperature, decreased leaf litter or woody debris) could alter community composition, thus biological integrity.

Water chemistry is the most commonly considered factor controlling biological integrity because we have long recognized that biological organisms have specific tolerances and requirements. Exceedance of species tolerances (e.g., dissolved oxygen, pH) may reduce or eliminate populations thus altering biological integrity.

Proliferation of aquatic organisms is dependent on adequate physical habitat, including substrate, current, and temperature. Diversity of physical habitat generally supports larger number of community members. If the diversity of physical habitat is reduced (e.g., channel widened, channel straightened, woody debris removed, etc.) fewer species may find suitable conditions for feeding and reproduction, thus altering community structure.

3. Data Used in Stressor Identification

The BSID analysis is based primarily on the MDDNR MBSS round two dataset. This principal dataset uses a statewide probability-based sampling design to assess the biological condition of first-, second-, third-, and fourth-order non-tidal streams (determination based on the solid blue line shown on U.S. Geological Survey 1:100,000-scale maps) within Maryland's 8-digit watersheds (Klauda et al. 1998, Roth et al. 2005). MDDNR MBSS sites are sampled within a 75-meter segment of stream length. The MDDNR MBSS conducted two rounds of sampling between 1995 and 2004. BSID analysis was constrained to the round two MDDNR MDSS dataset (2000 -2004) because it provides a broad spectrum of paired data variables (i.e., in-stream biological data are paired with chemical, physical, and land use variables).

MDE conducted a thorough data quality review and vetting process of all MDDNR MBSS round two data to ensure that they meet the biological listing methodology criteria of the Integrated Report (MDE 2008). The final master dataset contains all round two biological sites considered valid for use as the principal dataset for BSID analysis and the listing process.

The round two dataset contains counts from numerous taxonomic groups (i.e., fish, macroinvertebrates, reptiles, amphibians), has more than 190 abiotic parameters, and identifies upstream drainage areas for calculation of spatial information (e.g., land use proportions). Each abiotic parameter represents a specific ecosystem component within the watershed (i.e., physical habitat, water chemistry, and land use sources).

The MDDNR MBSS dataset has three data types for abiotic parameters. First, there are quantitative parameters (e.g. chemical data) that can be classified as continuous as they have a wide range of numerical values. Next, there are qualitative habitat parameters that can be classified as ordinal as these are typically integer values with a logical numerical order (scale 20-0). Finally, there are binary variables that have a logical present or absent (yes/no) value.

MDE reviewed the abiotic information from the principal dataset and selected parameters that represent stressors causing biological degradation (i.e. sediment, habitat conditions, and water chemistry), and sources of stressors (i.e. land use and sources of acidity). Target values for these parameters were established to indicate a threshold above which degradation to biological communities will likely occur.

The State of Maryland is required to consider all readily available data for listing impairments in the Integrated Report; therefore, relevant data from federal, state, and county environmental programs, and from private organizations, will be reviewed for possible inclusion into the principal dataset. For inclusion in the principal dataset, all relevant data must incorporate all MDDNR MBSS round two parameters and be consistent with all MDDNR MBSS protocols.

4. Stressors and Sources

Parameters were selected from the principal dataset to represent either specific “stressors” or potential “sources” of stressors causing biological degradation. Parameters representing stressors are grouped into four categories: 1) sediment transport and deposition, 2) habitat condition, 3) riparian habitat condition, and 4) water chemistry. Parameters representing potential sources of stressors are grouped into two categories: land uses within a watershed and potential sources of acidity.

4.1. Stressors

4.1.1 Indicators of Sediment Transport and Deposition

MDE selected several parameters from the principal dataset that evaluates the overall amount of sedimentation in the stream and provides information about the hydrologic regime of the watershed. The sedimentation parameters used in the BSID analysis are: bar formation, channel alteration, embeddedness, epifaunal substrate, presence of erosion, bank stability, and presence of silt/clay. Each of these parameters is measured once during summer index period.

<u>Bar Formation</u>

Bar Formation represents deposition of sand, gravel, and small stones in an area of the stream with a gentle slope and an elevation very close to the stream’s water level. Bar formation typically reflects the overall sediment transport capacity of the stream with observed categories of moderate to extensive or extensive bar formation present. Moderate to extensive bar formation indicates channel instability related to frequent and intense high stream velocities that quickly dissipate and rapidly lose the capacity to transport excessive sediment loads downstream.

Sediment loads may originate from terrestrial (surface) erosion or from in-stream channel/bank erosion. Excessive sediment loading is expected to reduce and homogenize available feeding and reproductive habitat, degrading biological conditions. Distinguishing between terrestrial or aquatic sources of sediment is not possible from this measure. Since many pollutants readily attach to sediment particles, it is possible that this parameter may also represent the presence of pollutants other than sediment. For example, sediment loads from terrestrial erosion may also introduce phosphorus into the stream segment. Conditions indicating biological degradation are *bar formation present*, *moderate bar formation present* and *extensive bar formation present.*

<u>Channel Alteration</u>

Channel Alteration is a rating of large-scale changes in the shape of a stream channel. This rating addresses deliberate stream manipulations within a 75-meter sample station (e.g., concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures), as well as stream alterations resulting from large changes in hydrologic energy (e.g., recent bar development). Deliberate alterations typically result in higher velocities by smoothing channel surfaces, straightening channels, or raising/steepening banks. Thus, the presence of alterations assessed in this rating is considered to demonstrate increased probability that the stream is prone to frequent high velocities. The corresponding occurrence of more frequent low discharges is also expected, due to reduced base flow resulting from rapid exit of water from a watershed. Many channel alterations may also directly reduce habitat heterogeneity.

Channel alteration is described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels. The first level, *poor channel alteration*, is defined as heavy deposits of fine material and/or extensive bar development, or recent channelization, or evidence of dredging, or greater than 80% of the banks artificially armored. The second level, marginal channel alteration, is defined as recent but moderate deposition of gravel and sand on bars and/or embankments; and/or 40% to 80% of banks artificially armored or channel lined in concrete. Conditions indicating biological degradation for the BSID analysis are *channel alteration marginal to poor* and *channel alteration poor*.

Embeddedness

Embeddedness is determined by the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. Embeddedness is categorized as a percentage from 0% to 100% with low values as optimal and high values as poor. High embeddedness is a result of excessive sediment deposition.

High embeddedness suggests that sediment may interfere with feeding or reproductive processes and result in biological impairment. Although embeddedness is confounded by natural variability (e.g., Coastal Plain streams will naturally have more embeddedness than Highlands streams), embeddedness values higher than reference streams are indicative of anthropogenic sediment inputs from overland flow or stream channel erosion.

Embeddedness threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. A final threshold value is set based on review of the results. Levels above the threshold percentages may indicate biological degradation.

Threshold values indicating embeddedness were identified for two regions, the Highland (50%) and Eastern Piedmont (50%) (see Appendix A: Table A-1). Because the Coastal Plain is naturally embedded, there was no significant difference between 90th percentile embeddedness values for very poor and good sites. Based on the results, the threshold value set for the Highland and Eastern Piedmont is 50% embedded. A threshold of 100% was applied to the Coastal Plain, as embeddedness is not a good indicator in this region. Applying these thresholds value to individual sites allows the determination of the *high embeddedness* condition considered for the BSID.

Epifaunal Substrate Condition

Epifaunal Substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. The varied habitat types such as cobble, woody debris, aquatic vegetation, undercut banks, and other commonly productive surfaces provide valuable habitat for benthic macroinvertebrates. Like embeddedness, epifaunal substrate is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates.

Epifaunal substrate conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon. Conditions considered for the BSID analysis are *epifaunal substrate marginal to poor* and *epifaunal substrate poor.*

Erosion Severity

Erosion Severity represents a visual observation that the stream discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy, resulting in channel instability, which in turn affects bank stability. Where such conditions are observed, flow energy is considered to have increased in frequency or intensity, accelerating channel and bank erosion. Increased flow energy suggested by this measure is also expected to negatively influence stream biology.

Erosion severity is described categorically as minimal, moderate, or severe. Conditions indicating biological degradation are set at two levels, moderate and severe. A level of *severe* indicates that a substantial amount of stream banks show severe erosion and the stream segment exhibits high levels of instability due to erosion. A level of moderate indicates that a marginal amount of stream banks show erosion and the stream segment shows elevated levels of instability due to erosion. Conditions considered for the BSID analysis are *moderate to severe erosion present* and *severe erosion present.*

Bank Stability Index

Bank stability index is a composite score that combines a visual rating based on the presence or absence of riparian vegetation and other stabilizing bank materials (e.g., boulders, root-wads) with quantitative measures of erosion extent and erosion severity. Banks Stability Index is based on a numeric score from 0-20, with low values as poor and high values as optimal. A poor bank stability index score indicates that the amount of stream bank soil that is being eroded and deposited in the stream is likely different from sites with fair to good biological conditions.

Bank stability index converts the MDDNR MBSS 2000 erosion extent into a numeric score from 0 – 20 using the following formula (source):

$$\text{Bank Stability Index} = \left[\frac{\text{Erosion Extent}}{-15}\cdot\text{Severity}\right]_{\text{Left bank}} + \left[\frac{\text{Erosion Extent}}{-15}\cdot\text{Severity}\right]_{\text{Right bank}} + 20$$

In short, bank stability is a measure of channel erosion. Lower scores on this index are considered to demonstrate that discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy. The index may further identify conditions, in which stream banks are vulnerable regardless of flood severity or frequency, thus demonstrate increased probability of high sediment loadings.

Bank stability index threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation due to bank stability were identified for two regions; the Highland (10) and Eastern Piedmont (6) (see Appendix A: Table A-2). The Coastal Plain region did not show any statistically significant difference between 90th percentile bank stability index values for very poor and good sites. Based on the results, the threshold value set for the Highland is (10), Eastern Piedmont (6) and the Coastal Plain (10). The Coastal Plain threshold was applied since this is the middle point of the metric (e.g. 1 to 20). Applying these threshold values to individual sites allows the determination of the *poor bank stability index* condition considered for the BSID.

Silt/Clay

Silt/Clay represents indications of the obvious presence of silt and/or clay in a stream channel, suggesting that sediment loading exceeds the transport capacity of the stream. Accumulations of sediment may interfere with feeding or reproductive processes, which may eliminate or reduce species occurrence, resulting in community structure alteration. Silt/clay is a presence/absence binary data result. The condition considered for the BSID analysis is *silt/clay present.*

4.1.2 Indicators of In-stream Habitat Conditions

MDE selected several qualitative parameters from the principal dataset that evaluate the overall physical in-stream habitat conditions of the watershed. The habitat parameters used in the BSID analysis are: presence of channelization, in-stream habitat, pool/glide/eddy quality, riffle/run quality, velocity/depth diversity, presence of concrete/gabion, and presence of beaver ponds. Each of these parameters is measured during spring and/or summer index period.

Channelization

Channelized describes a condition determined by visual observation of the presence or absence of the channelization of the stream segment and the extent of the channelization. Channelization is the human alteration of the natural stream morphology by altering the stream banks, (i.e., concrete, rip rap, and ditching). Streams are channelized to increase the efficiency of the downstream flow of water. Channelization likely inhibits heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities. The condition considered for the BSID analysis is *channelization present.*

In-stream Habitat Condition

In-stream Habitat is a visual rating based on the perceived value of habitat within the stream channel to the fish community. Multiple habitat types, varied particle sizes, and uneven stream bottoms provide valuable habitat for fish. High in-stream habitat scores are evidence of the lack of sediment deposition. Like embeddedness, in-stream habitat is confounded by natural variability (i.e., some streams will naturally have more or less in-stream habitat). Low in-stream habitat values can be caused by high flows that collapse undercut banks and by sediment inputs that fill pools and other fish habitats.

In-stream habitat conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, which is defined as less than 10% stable habit where lack of habitat is obvious; and 2) marginal, where there is a 10-30% mix of stable habitat but habitat availability is less than desirable. 'Marginal' and/or 'poor' ratings of this measure indicate excessive erosion and/or sedimentation. Conditions considered for the BSID analysis are and *in-stream habitat structure marginal to poor* and *in-stream habitat structure poor*.

Pool/glide/eddy Quality

Pool/glide/eddy (P/G/E) quality is a visual observation and quantitative measurement of the variety and spatial complexity of slow or still water habitat and cover within a stream segment. Stream morphology complexity directly increases the diversity and abundance of fish species found within the stream segment. The increase in heterogeneous habitat such as a variety in depths of pools, slow moving water, and complex covers likely provide valuable habitat for fish species; conversely, a lack of heterogeneity within the P/G/E habitat decreases valuable habitat for fish species.

P/G/E quality conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels 1) poor, defined as minimal heterogeneous habitat with a max depth of <0.2 meters or being absent completely; and 2) marginal, defined as <10% heterogeneous habitat with shallow areas (<0.2 m) prevalent and slow moving water areas with little cover. Conditions considered for the BSID analysis are *pool/glide/eddy quality marginal to poor* and *pool/glide/eddy quality poor.*

Riffle/Run Quality

Riffle/Run Quality is a visual observation and quantitative measurement based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. Like P/G/E quality, an increase of heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity.

Riffle/run quality conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity. Conditions considered for the BSID analysis are *riffle/run quality marginal to poor* and *riffle/run quality poor*.

Velocity Depth Diversity

Velocity/Depth Diversity is a visual observation and quantitative measurement based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). Like riffle/run quality, the increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The 'marginal' or 'poor' diversity categories could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock), anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.), or excessive erosional conditions (e.g., bar formation, entrenchment, etc.).

Velocity/depth diversity conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, defined as the stream segment being dominated by one velocity/depth regime, usually pools; and 2) marginal, defined as having only two out of the four velocity/depth diversity regimes present with in the stream segment. Conditions considered for the BSID analysis are *velocity/depth diversity marginal to poor* and *velocity/depth diversity poor*.

Concrete

The presence or absence of concrete is determined by a visual observation within the stream segment, resulting from the field description of the types of channelization. Like the parameter channelization, concrete inhibits the heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities. Concrete channelization increases flow and provides a homogeneous substrate, conditions which are detrimental to diverse and abundant colonization. The condition considered for the BSID analysis is *concrete/gabion present.*

Beaver Dam

The presence or absence of a beaver pond within the stream segment is determined from a visual observation. Beaver dams often create stream impoundments causing numerous physical and chemical changes of a free flowing stream resulting in a more lentic environment. These impoundments create a physical barrier within the stream preventing fish migration. Natural biological response to beaver activity may appear to suggest that a stream's biological community is 'impaired' because the biotic composition differs from regional reference stations. The presence of beaver pond at a station will demonstrate the potential for natural community alteration to explain low IBI scoring. Beaver pond is categorized as a presence/absence binary data result. The condition considered for the BSID analysis is *beaver pond present.*

4.1.3 Indicators of Riparian Habitat Condition

MDE selected two parameters from the principal dataset that evaluate the overall riparian habitat conditions of the watershed. The riparian habitat parameters used in the BSID analysis are: riparian buffer width and shading. Each of these parameters is measured once during summer index period.

Riparian Buffer Width

Riparian Buffer Width represents the minimum width of vegetated buffer in meters, looking at both sides of the stream. Riparian buffer width is measured from 0 m to 50 m, with 0 m having no buffer and 50 m having a full buffer. Riparian buffers serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee et al. 2004).

Riparian buffer threshold values are determined by comparing the 10th percentile width among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results. Levels below the threshold may indicate biological degradation.

A statistically significant minimum riparian buffer threshold value was not identified when considering data statewide or within any of the three eco-regions. It was decided that a stream segment having no (zero meters) riparian buffer width would indicate a potential impact to biological degradation (see Appendix A: Table A-3). The condition considered for the BSID Analysis is *no riparian buffer.*

Shading

Shading is a metric indicating the percentage of the stream segment that is shaded, taking duration into account. Because solar radiation increases the temperature of the stream segment, causing thermal stress on fish and invertebrates, shading is important in protecting the stream from this impact. Other impacts from increased water temperature are decreased dissolved oxygen, and increased bacterial and algal growth.

Shading threshold values are determined by comparing the 10^{th} percentile value among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation for shading were identified for the State (50%) and in one region, Coastal Plain (55%) (see Appendix A: Table A-4). The Highland and Eastern Piedmont did not show any statistically significant difference between 90^{th} percentile shading values for very poor and good sites. Based on the results, a threshold was set for the state at 50%. Applying the aforementioned thresholds to individual sites allow the determination of the *low shading* condition considered for the BSID.

4.1.4 Indicators of Water Chemistry Conditions

MDE selected several quantitative parameters from the principal dataset that evaluates the overall water quality of a stream and provides information about nutrient and inorganic loading. The water quality parameters used in the BSID analysis are: total phosphorus, ortho-phosphate, total nitrogen, dissolved nitrogen, ammonia, pH (lab), ANC, chlorides, conductivity (lab), and sulfates. Each of these parameters is measured once during the spring index period. In addition, in situ measurements of dissolved oxygen, pH (field), conductivity (field), and temperature are taken once during the summer index period.

Total Phosphorus

Total phosphorus (TP) is a measure of the amount of TP in the water column. Phosphorus forms the basis of a very large number of compounds, the most important class of which is the phosphates. For every form of life, phosphates play an essential role in all energy-transfer processes such as metabolism and photosynthesis. About three-quarters of the TP (in all of its chemical forms) used in the United States goes into fertilizers. Other important uses are as builders for detergents and nutrient supplements for animal feeds. Phosphorus plays a crucial role in primary production. Elevated levels of phosphorus can lead to excessive growth of filamentous algae and aquatic plants. Excessive phosphorus input can also lead to increased primary production, which potentially results in species tolerance exceedances of dissolved oxygen and pH levels. TP input to surface waters typically increases in watersheds where urban and agricultural developments are predominant.

TP threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation for TP were identified for the State and all three regions (see Appendix A: Table A-5). Based on the results, threshold concentrations were set for the three regions at 0.06 mg/L (Highland), 0.06 mg/L (Eastern Piedmont), and 0.14 mg/L (Coastal Plain). Applying these thresholds to individual sites allow the determination of the *high total phosphorus* condition considered for the BSID.

Orthophosphate

Orthophosphate (OP) is a measure of the amount of OP in the water column. OP is the most readily available form of phosphorus for uptake by aquatic organisms (see 'Total Phosphorus' above). OP threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation for OP were identified for the State (0.02 mg/L) and one region, the Highland (0.02 mg/L) (see Appendix A: Table A-6). The Eastern Piedmont and Coastal Plain regions did not show any statistically significant difference between 90th percentile OP values for very poor and good sites. Based on the results, threshold concentrations were set for the state at 0.02 mg/L. Applying the threshold to individual sites will allow the determination of the *high orthophosphate* condition considered for the BSID.

Total Nitrogen

Total nitrogen (TN) is a measure of the amount of TN in the water column. TN is comprised of organic nitrogen, ammonia nitrogen, nitrite and nitrate. Nitrogen plays a crucial role in primary production. Elevated levels of nitrogen can lead to excessive growth of filamentous algae and aquatic plants. Excessive nitrogen input also can lead to increased primary production, which potentially results in species tolerance exceedances of dissolved oxygen and pH levels. Runoff and leaching from agricultural land can generate high in-stream levels of nitrogen.

TN threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results and consideration of other information.

A threshold value indicating potentially significant biological degradation for TN was identified for only one region, Highland (3.0 mg/L) (see Appendix A: Table A-7). The Statewide, Eastern Piedmont, and Coastal Plain regions did not show any statistically significant difference between 90th percentile TN values for very poor and good sites. It is also important to note that in the Eastern Piedmont that higher levels of TN were found in Good sites, when compared to the Poor sites. The threshold is also the same as the Enhanced Nutrient Removal (ENR) threshold for wastewater treatment plants in Maryland. Based on the results, threshold concentrations were set for the three regions at 3.0 mg/L. Applying the threshold to individual sites will allow the determination of the *high total nitrogen* condition considered for the BSID.

Total Dissolved Nitrogen

Total dissolved nitrogen (TDN) is a measure of the amount of dissolved nitrogen in the water column. Nitrogen plays a crucial in primary production. Dissolved nitrogen is the most readily available form of phosphorus for uptake by aquatic organisms (see 'Total Nitrogen' above).

TDN threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results and consideration of other information.

A threshold value indicating potentially significant biological degradation for TDN was identified for only one region, Highland (3.0 mg/L) (see Appendix A: Table A-8). This is the same threshold used for TN (see section 3.2.1). Based on the results and using the same rationale as applied in setting the TN threshold, threshold concentrations were set for the three regions at 3.0 mg/L. Applying the threshold to individual sites to allow the determination of the *high total dissolved nitrogen* condition considered for the BSID.

Dissolved Oxygen

Dissolved Oxygen (DO) is a measure of the amount of oxygen dissolved in the water as a function of variables such as water temperature, atmospheric pressure, physical aeration, and chemical/biological oxygen demand. DO is generally reported as a concentration (mg/L). MDDNR MBSS measures DO in situ once during the summer. Low DO concentrations may indicate organic pollution due to heterotrophic oxygen consumption and may stress aquatic organisms. Low DO concentrations are considered to demonstrate excessive oxygen demand, primarily from decomposition of organic material. Sources are agricultural, forested, and urban land uses.

The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by COMAR 2007. Applying the threshold of 5.0 mg/L to individual sites will allow the determination of the *low dissolved oxygen* condition considered for the BSID.

Dissolved Oxygen Saturation

DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. Percent saturation is relative to the amount of oxygen that water can hold, as determined by temperature and atmospheric pressure. MDDNR MBSS only measures DO concentrations expressed in mg/L; therefore, MDE calculated DO saturation percentages. DO saturation, expressed in mg/L, depends on water temperature and salinity. Percent saturation is the ratio of observed DO to DO saturation value, expressed as a percent.

$$T_a = \text{temp\_fld} + 273.15$$

where temp_fld is the DNRMBSS recorded temperature at a specified station and T_a = absolute temperature (K).

$$\ln O_{sf} = -139.34411 + \frac{1.575701 * 10^5}{T_a} - \frac{6.642308 * 10^7}{T_a^2} + \frac{1.243800 * 10^{10}}{T_a^3} - \frac{8.621949 * 10^{11}}{T_a^4}$$

$$O_{sf} = e^{\ln O_{sf}}$$

where O_{sf} = saturation concentration of dissolved oxygen in fresh water at 1 atm (mg $L^{-1})$ and e is the irrational constant = 2.718281828459.

$$O_{sp} = O_{sf} * (1 - .000035 * \text{altitude\_f})$$

where $O_{sp} =$ saturation concentration of dissolved oxygen at a specified elevation and altitude_f is the altitude of a specified DNRMBSS station.

$$\text{dosat\_fld} = \frac{\text{do\_fld}}{O_{sf}}$$

where dosat_fld is the percent DO saturation and do_fld is the DNRMBSS recorded Dissolved Oxygen in situ at a specified station.

Natural diurnal fluctuations can become exaggerated in streams with excessive primary production, enabling stressor risk analyses. DO saturation levels less than 60% saturation (like DO concentrations <5mg/L) are considered to demonstrate high respiration associated with excessive decomposition of organic material. Additionally, DO saturation greater than 125% is considered to demonstrate oxygen production associated with high levels of photosynthesis. Sources are agricultural, forested and urban land uses.

The DO saturation threshold values, at which concentrations below 60% and above 125% may indicate biological degradation are established from peer-reviewed literature (CIESE 2008). Applying the thresholds of 60% and 125% to individual sites will allow the determination of the *low dissolved oxygen saturation* and *high dissolved oxygen saturation* conditions considered for the BSID.

Ammonia

Ammonia (NH_3) is a measure of the amount of NH_3 in the water column. NH_3 is a nitrogen nutrient species; in excessive amounts it has potential toxic effects on aquatic life. Increased nutrient loads from urban and agricultural development are a source of NH_3. Ammonia is associated with increased primary production, increased pH, increased sunlight exposure, and high water temperature.

Ammonia toxicity is reported in four categories: ammonia acute with salmonid present, ammonia acute with salmonid absent, ammonia chronic with salmonid present, and ammonia chronic with salmonid absent. Ammonia acute toxicity with salmonid present or absent refers to potential exceedences of species tolerance caused by a one-time, sudden, high exposure of ammonia. Chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time.

MDDNR MBSS collects water chemistry samples for un-ionized ammonia (NH_3) and pH during the spring index period. The USEPA numeric criterion for ammonia is reported for total ammonia in N mg/l and is pH, temperature, and life stage dependent. NH_3 threshold values are determined by using USEPA ammonia criteria (USEPA 2006) for freshwater with appropriate conversion. Concentrations above the threshold value may indicate biological degradation.

In surface water, un-ionized ammonia exists in equilibrium with ammonium and hydroxide ions. The equilibrium constant for this reaction is dependent on temperature and pH values of the stream segment. Thus, if temperature and pH are known for a stream segment, the fraction of un-ionized ammonia can be calculated. Then, if ammonia in N mg/l is known from USEPA numeric criteria, the un-ionized ammonia numeric criteria can be calculated.

The ammonia criteria in COMAR is calculated as follows:

1. The one-hour average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than every three years on the average, the acute criterion (CMC) calculated using equations:

    a. Where salmonid fish are present:
    $CMC = (0.275/(1 + 10^{7.204-pH})) + (39.0/(1 + 10^{pH-7.204}))$

    b. Where salmonid fish are absent:
    $CMC = (0.411/(1 + 10^{7.204-pH})) + (58.4/(1 + 10^{pH-7.204}))$

2. The thirty-day average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every three years on the average, the chronic criterion (CCC) calculated using equations:

    a. Where salmonid fish are present:
    $CCC = ((0.0577/(1 + 10^{7.688-pH})) + (2.487/(1 + 10^{pH-7.688}))) \text{ x MIN } (2.85, 1.45 \cdot 10^{0.028 \cdot (25-T)})$

    b. Where salmonid fish are absent:
    $CCC = ((0.0577/(1 + 10^{7.688-pH})) + (2.487/(1 + 10^{pH-7.688}))) \text{ x } 1.45 \cdot 10^{0.028 \cdot (25-MAX(T,7))}$

3. In addition, the highest four-day average within the thirty-day period should not exceed 2.5 times the CCC.

The conversion from ammonia in mg N mg/l, which is reported in COMAR, to un-ionized ammonia, which is collected by MDNR MBSS in the spring index period, is required for comparison of MBSS to the water quality criteria.

The conversion begins with specifying a pH within the valid range of the criteria. While the equation developed by EPA, and presented in COMAR, is valid for a pH range between 6.0 and 10.0, a pH range between 6.5 and 9.0 was selected for consistency with the pH tables listed in COMAR (COMAR 2007a). Therefore if the pH is less than 6.5 it is adjusted up to 6.5 and if the pH is greater than 9.0 it is adjusted down to 9.0.

Next, an equilibrium constant is defined ad follows:

$$pK_a = 0.09018 + 2729.92 / (273.2 + T_k)$$

where

pKa = equilibrium constant
T_k = average water temperature in degrees C.

Because water temperature is not collected in the MBSS spring index period (i.e. with ammonia samples) an average water temperature was estimated for each physiographic region using data from a representative Maryland CORE/Trend station. The water temperatures applied in the three regions were 7.0º C (Highland), 7.0º C (Eastern Piedmont), and 10.0º C (Coastal Plain).

Once the equilibrium constant and pH are specified for a site, the mole fraction of un-ionized ammonia is calculated by the following equation:

$$f = \frac{1}{(10^{(pK_a - pH)} + 1)}$$

Finally, the amount of total ammonia (expressed in mg N/l) for the COMAR criteria can be converted to total un-ionized ammonia (expressed in mg N/l), which is the same for of ammonia reported by MDNR MBSS for the spring index period, using the following equation:

$$NH_3 = \mathrm{NH}_4 * f * \left(17/14\right),$$

where

NH^3 = un-ionized ammonia mg/l
NH^4 = ammonia mg N/l
f = mole fraction of un-ionized ammonia17/14 is the formula weight of NH^3 divided by the formula weight of N

Applying the criteria to individual sites allows the determination of the a*mmonia chronic with salmonid present, ammonia chronic with salmonid absent, ammonia acute with salmonid present* and a*mmonia acute with salmonid absent* conditions considered for the BSID.

pH

pH is a measure of the acid balance of a stream and uses a logarithmic scale range from 0 to 14, with 7 being neutral. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). Most stream organisms prefer a pH range of 6.5 to 8.5. Values of less than 6.5 for pH are considered to demonstrate acidity, which can be damaging to aquatic life. Intermittent high pH (greater than 8.5) is often associated with eutrophication related to increased algal blooms. Exceedances of pH may allow concentrations of toxic elements (such as ammonia, nitrite, and aluminum) and high amounts of dissolved heavy metals (such as copper and zinc) to be mobilized for uptake by aquatic plants and animals.

The pH threshold values, at which levels below 6.5 and above 8.5 may indicate biological degradation, are established from state regulations (COMAR 2007a). Low stream pH results from agricultural land use, acid mine drainage, atmospheric deposition and organic sources. High stream pH results from agricultural and urban land uses. Applying the low and high thresholds to individual sites will allow the determination of the *low lab pH, high lab pH, low field pH, and high field pH* conditions considered for the BSID.

Acid Neutralizing Capacity

Acid Neutralizing Capacity (ANC) is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. MDDNR MBSS measures ANC in the spring and reports it as µeq/L. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. An ANC value above 200µeq/l is considered normal (Southerland et al 2007). Repeated additions of acidic materials may cause a decrease in ANC. ANC values less than 50µeq/l are considered to demonstrate chronic (highly sensitive to acidification) exposures for aquatic organisms, and less than 200 are considered to demonstrate episodic (sensitive to acidification) exposures.

The ANC threshold values, at which levels below 50 (chronic) and below 200 (episodic) may indicate biological degradation, are established from peer-reviewed literature (Kazyak et al 2005, Southerland et al 2007). Low ANC results from agricultural land use, acid mine drainage, atmospheric deposition and organic sources. Applying the thresholds to individual sites will allow the determination of the *acid neutralizing capacity below chronic level* and *acid neutralizing capacity below episodic level* conditions considered for the BSID.

Chlorides

Chloride is a measure of the amount of dissolved chloride (CL^-) in the water column. MDDNR MBSS measures chlorides during the spring index period and reports it as mg/L. Chlorides can play a critical role in the elevation of conductivity (an indicator of the presence of dissolved substances). Most fish and benthic communities cannot survive in waters with high levels of chlorides. Excessive chloride concentrations indicate a potentially damaging chemical content to stream biology.

High concentrations of chlorides can be due to several types of pollution, including industrial discharges, leaking wastewater infrastructure, metals contamination, and application of road salts in urban landscapes. Although chloride can originate from natural sources, most of the chloride that enters the environment is associated with the storage and application of road salt. Road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality. Approximately 55% of road-salt chlorides are transported in surface runoff, with the remaining 45% infiltrating through soils and into groundwater aquifers (Church and Friesz, 1993).

Chloride threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation for CL^- were identified for the State and all three regions (see Appendix A: Table A-9). Based on the results, threshold concentrations were set for the three regions at 50.0 mg/L (Highland), 50.0 mg/L (Eastern Piedmont), and 50.0 mg/L (Coastal Plain). Since analysis for all regions resulted in a threshold value 50.0mg/L, this threshold was applied to all sites.
Applying these thresholds to individual sites allow the determination of the *high chlorides* condition considered for the BSID.

Conductivity

Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. MDDNR MBSS collects conductivity samples once during the spring, which is analyzed in the laboratory (*conductivity lab*), and measured once in situ during the summer (*conductivity field*).

Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions such as chloride, sulfate, carbonate, sodium, and phosphate. Stream conductivity is determined primarily by the geology of the area through which the stream flows. Streams supporting fish assemblages usually have a range between 150 and 500 µS/cm; conductivity outside this range may indicate that the water is unsuitable for certain species of fish and/or macroinvertebrates resulting a shift to more salinity-tolerant species.

Conductivity threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont, and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation for conductivity were identified for the State and all three regions (see Appendix A: Table A-11). Based on the results, threshold concentrations were set for the three regions at 500 µS/cm (Highland), 300µS/cm (Eastern Piedmont), and 300 µS/cm (Coastal Plain). Applying these thresholds to individual sites allow the determination of the *high conductivity* condition considered for the BSID.

Sulfates

Sulfate is the amount of dissolved sulfate (SO_4^{2-}) in the water column. MDDNR MBSS measures sulfate once in the spring and reports it as mg/L. Sulfur is an essential plant nutrient. Sulfates can play a critical role in the elevation of conductivity. Other detrimental impacts of elevated sulfates are their ability to form strong acids, which can lead to changes of pH levels in surface waters.

Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater dischargers. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals.

Sulfate threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation for sulfate were identified for the State and all three regions (see Appendix A: Table A-11). Based on the results, threshold concentrations were set for the three regions at 32.0 mg/L (Highland), 21.0 mg/L (Eastern Piedmont), and 28.0 mg/L (Coastal Plain). Applying these thresholds to individual sites allow the determination of the *high sulfate* condition considered for the BSID.

4.2. Sources

MDE selected parameters from the principal dataset to represent potential "sources" of stressors. Parameters representing sources of stressors are grouped into two categories: land uses within a watershed and potential sources of acidity.

The majority of landscape data evaluated in BSID analysis is land use land cover (LULC) data that was developed by MDE for each MDDNR MBSS site, and enabled calculation of LULC proportions for the 60-meter riparian areas upstream of the site as well as whole watershed areas upstream of the site. ArcGIS and Spatial Analyst (ESRI, 1999) were used to identify and quantify LULC categories from the 2000 RESAC dataset. The datasets was derived from LandSat imagery and have a resolution of 900m^2. Land use parameters used in the BSID analysis were grouped into four categories: urban, agricultural, barren, and anthropogenic.

As anthropogenic disturbance increases, biological condition in our rivers and streams generally decreases. However, land use is broadly associated with the biological condition of aquatic systems and does not provide the specificity to isolate and identify in-stream stressors responsible for observed biological conditions. While not independently useful in identifying biological stressors, land use data does enhance understanding of the influence of in-stream chemical and physical stressors. Land uses are considered sources of many biological stressors, for example pH, ammonia, and chlorides. However, causal sources are given far less weight than in-stream stressors in the final interpretation of causation in the risk analyses results.

MDE also selected numerous parameters within the principle dataset that represent sources of acidity to be included as causal sources. Increased acidity within a stream, resulting in levels that exceed species tolerance, may indicate biological degradation to biological communities. Sources of acidity represent acidic conditions due to loads from land use and chemical sources (i.e., atmospheric deposition, acid mine drainage, organic sources, and agricultural influences). MDNR MBSS derived the possible sources of acidification from analyzing water chemistry data collected by the Maryland Synoptic Stream Chemistry Survey (MSSCS) and other regional data (Southerland et al. 2005a).

4.2.1 Urban Land Use

Impervious Surface in Watershed

Impervious surface is any land area that does not permit precipitation to percolate into the ground, including natural and anthropogenic surfaces. Human development typically increases the amount of impervious surface in a watershed by replacing natural vegetation and soils with buildings and pavement. A high proportion of impervious surface will result in increased surface flow and more rapid transport of precipitation out of a watershed. Increased surface flows to streams can result in more pollutant transport that may exceed species tolerances. The increased speed of runoff also overpowers any natural stream morphology formed to attenuate flow energy, such as meanders and floodplains. As streams adjust to changes in flow energy, they are unstable and are subject to rapid changes in morphology that could episodically displace aquatic organisms as habitats are gained and lost. Aquatic organisms may also be repeatedly scoured from stream channels where high flows are experienced more frequently than in watersheds with low amounts of impervious surface.

Impervious surface land use threshold values are determined by comparing the 90^{th} percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-12). Based on results, thresholds were set for the three regions at 5% (Highland), 5% (Eastern piedmont), and 10% (Coastal plain).

Applying these thresholds value to individual sites allows the determination of the *high % of impervious surface in watershed* condition considered for the BSID.

High Intensity Urban in Watershed

Watershed high intensity urban represents the proportion of medium and high intensity developed land as well as transportation area within the entire drainage basin for each stream station. As with measures of impervious surface, high intensity urban increases surface water flow, or otherwise speeds water delivery to stream channels (e.g., storm water pipes), increasing the energy of flowing water and the potential to erode soils (on the terrain and in stream channels), carry pollutants, and displace organisms. Expedited transport of water from a basin decreases groundwater recharge and amplifies both high and low flow extremes. Increased pollutant transport could include nutrients, organics, and/or inorganics from residential, commercial, and/or industrial activities associated with this land usage. Reduction of available heterotrophic material could also shift trophic conditions in aquatic systems to more autotrophic that could also alter biological community structure.

High Intensity land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-13). Based on results, thresholds were set for the three regions at 6% (Highland), 10% (Eastern piedmont), and 10% (Coastal plain). Applying these thresholds value to individual sites allows the determination of the *high % of high intensity urban in watershed* condition considered for the BSID.

High Intensity Urban in 60m Stream Buffer

Stream buffer high intensity urban represents the proportion of medium and high intensity developed land and transportation area within 60 meters of streams upstream from sample stations. This measure does not convey the total system flow energy potential or whole basin high intensity urban proportions. Instead, it demonstrates the increased potential for pollutants to enter streams due to proximity and the corresponding lack of natural buffers to filter pollutants. High proportions also demonstrate the increased potential for encroachment of urban development on floodplains, which could reduce flow attenuation properties thereby increasing storm flow velocity and channel erosion.

High Intensity within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating

biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.
Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-14). Based on results, thresholds were set for the three regions at 6% (Highland), 6% (Eastern piedmont), and 7% (Coastal plain). Applying these thresholds value to individual sites allows the determination of the *high % of high intensity urban 60m stream buffer* condition considered for the BSID.

Low Intensity Urban in Watershed

Watershed low intensity urban represents the proportion of low intensity developed land as well as urban/residential land areas dominated by deciduous trees, evergreen trees, mixed trees/forest, or recreational grasses within the entire drainage basin for each stream station. While impervious surface is expected in this land use classification, it is considered to be less extensive than in high intensity urban areas. Pollutant types are expected to be similar to those associated with high intensity urban. Episodic acute loads may equal the magnitude of high intensity area due, for example, to potential seasonal application of lawn fertilizers/pesticides or random illegal dumping of pollutants. However, chronic pollutant loads are expected to be less than those in high intensity settings due to the implied presence of natural vegetation associated with this land use classification.

Low Intensity land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-15). Based on results, thresholds were set for the three regions at 20% (Highland), 50% (Eastern piedmont), and 55% (Coastal plain). Applying these threshold values to individual sites allows the determination of the *high % of low intensity urban in watershed* condition considered for the BSID.

Low Intensity Urban in 60m Stream Buffer

Stream buffer low intensity urban represents the proportion of low intensity developed land as well as urban/residential land areas dominated by deciduous trees, evergreen trees, mixed trees/forest, or recreational grasses within 60 meters of streams upstream from sample stations. Episodic pollutant loads from this primarily residential land use have increased potential compared to whole basin classifications due to the proximity to streams.

Low Intensity within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-16). Based on results, thresholds were set for the three regions at 20% (Highland), 35% (Eastern piedmont), and 40% (Coastal plain). Applying these threshold values to individual sites allows the determination of the *high % of low intensity urban land 60m stream buffer* condition considered for the BSID.

Transportation Land Use in Watershed

This land use classification is a subset of high intensity urban because it one of the original RESAC categories that were reclassified to create the high intensity classification. Independently, it generally conveys the potential for increased surface runoff and transport of pollutants due to the largely impervious nature of roadways and railways.

Transportation land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-17). Based on results, thresholds were set for the three regions at 4% (Highland), 6% (Eastern piedmont), and 6% (Coastal plain). Applying these threshold values to individual sites allows the determination of the *high % of transportation in watershed* condition considered for the BSID.

Transportation Land Use in 60m Stream Buffer

Roadways and railways within 60 meters of streams upstream from sample stations is a subset of high intensity urban within buffers. Independently, this land use measure demonstrates the exaggerated potential of channel modifying encroachments of paved surfaces, walls, culverts, and bridges into flood plains. Reduced flow attenuation properties of floodplains as well as rapid delivery of surface flow and pollutants are potential effects associated with high proportions of this measure.

Transportation within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-18). Based on results, thresholds were set for the three regions at 5% (Highland), 5% (Eastern piedmont), and 3% (Coastal plain). Applying these threshold values to individual sites allows the determination of the *high % of transportation 60m stream buffer* condition considered for the BSID.

4.2.2 Agricultural Land Use

Total Agricultural Land in Watershed

Watershed agricultural land represents the proportion of land area used for pasture/hay as well as for production of row crops within the entire drainage basin upstream of sample stations. Possible stream consequences to large proportions of agricultural land may include increased loads of sediment, nutrients, and/or pesticides. This is an extremely variable land use classification that could represent conditions ranging from dense livestock feeding lots to broad hay fields with no exposed soils.

Agricultural land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

A threshold value indicating potentially significant biological degradation was identified for one region, Highland (55%) (see Appendix A: Table A-19). No statistically significant barren land in watershed threshold values was determined for the Eastern Piedmont and Coastal Plain physiographic region. Since only the Highland analysis resulted in a threshold value (55%), this threshold was applied to all sites. Applying the threshold to individual sites will allow the determination of the *high % of agriculture in watershed* condition considered for the BSID.

Total Agricultural Land in 60m Stream Buffer

This measure represents the proportion agriculture land area used for pasture/hay, livestock, and production of row crops within 60 meters of streams upstream from sample stations. Possible stream consequences to large proportions of agricultural land may include increased loads of sediment, nutrients, and/or pesticides. This is an extremely variable land use classification that could represent conditions ranging from dense livestock feeding lots to broad hay fields with no exposed soils.

Agriculture within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state (45%) and two regions, the Highland (45%) and Coastal Plains (45%) (see Appendix A: Table A-20). No statistically significant agriculture 60m stream buffer threshold values were determined for the Eastern Piedmont physiographic region. Because the statewide, Highland, and Coastal Plains analysis resulted in the same threshold value (45%), this threshold was applied to all sites. Applying these thresholds to individual sites allows the determination of the *high % of agriculture 60m stream buffer* condition considered for the BSID.

Cropland in Watershed

The proportion of cropland in the whole drainage basin above is a subset of total agriculture in the basin. This measure provides limited refinement of the diversity of land condition represented by agriculture. However, it is still a very broad classification that includes a wide range of nutrient and soil loading potential. Worst case scenarios may include the presence of exposed soils for extended, possibly wet, periods and broadcast spreading of fertilizers.

Cropland land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

A threshold value indicating potentially significant biological degradation was identified for one region, Highland (25%) (see Appendix A: Table A-21). No statistically significant threshold values for cropland in watershed were determined for the state, Eastern Piedmont and Coastal Plain physiographic region. Since only the Highland analysis resulted in a threshold value (25%), this threshold was applied to all sites. Applying the threshold to individual sites will allow the determination of the *high % of cropland in watershed* condition considered for the BSID.

Crop Land in 60m Stream Buffer

This measure represents the proportion row crops within 60 meters of streams upstream from sample stations. High proportions demonstrate the increased potential to transport sediment from exposed soils and nutrients from fertilizers into streams. However, the presence of exposed soils and application of fertilizers is extremely variable within this land use classification.

Cropland land use within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state (25%) and only one region, the Highland (20%) (see Appendix A: Table A-22). No statistically significant cropland 60m stream buffer threshold values were determined for the Eastern Piedmont and Coastal Plain physiographic region. Since only the Highland analysis resulted in a threshold value (20%), this threshold was applied to all sites. Applying these thresholds to individual sites allows the determination of the *high % of cropland 60m stream buffer* condition considered for the BSID.

Pasture/Hay in Watershed

The proportion of pasture/hay in the whole drainage basin above is also a subset of total agriculture in the basin. This measure also provides limited refinement of the diversity of land condition represented by agriculture because it still involves possibly the highest (dense animal feed lots) and lowest potential (hay fields) for nutrient and sediment loads.

Pasture/Hay land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

A threshold value indicating potentially significant biological degradation was identified for one region, Highland (35%) (see Appendix A: Table A-23). No statistically significant pasture/hay in watershed threshold values was determined for the Eastern Piedmont and Coastal Plain physiographic region. Since only the Highland analysis resulted in a threshold value (35%), this threshold was applied to all sites. Applying the threshold to individual sites will allow the determination of the *high % of pasture/hay in watershed* condition considered for the BSID.

Pasture/Hay in 60m Stream Buffer

This measure represents the proportion pasture/hay land use within 60 meters of streams upstream from sample stations. High proportions demonstrate the increased potential to transport sediment from exposed soils and nutrients from fertilizers due to proximity to streams. However, the presence of nutrients and exposed soil is extremely variable within this land use classification.

Pasture/Hay within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

Threshold values indicating potentially significant biological degradation were identified for the state (30%) and two regions, the Highland (30%) and Coastal Plains (20%) (see Appendix A: Table A-24). No statistically significant pasture/hay 60m stream buffer threshold value was determined for the Eastern Piedmont physiographic region. Because the statewide analysis and Highland analysis resulted in the same threshold value (30%), this threshold was applied to Eastern Piedmont region. Applying these threshold values to individual sites allows the determination of the *high % of pasture/hay 60m stream buffer* condition considered for the BSID.

4.2.3 Barren Land Use

Barren Land in Watershed

This measure represents the proportion of exposed rock, clay, sand, surfacing mining activities, etc within the entire drainage basin upstream of sample stations. Streams below barren areas could potentially experience altered flow regimes and increased sediment loads.

Barren land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

A threshold value indicating potentially significant biological degradation was identified for one region, Highland (1%) (see Appendix A: Table A-25). No statistically significant barren land in watershed threshold values was determined for the Eastern Piedmont and Coastal Plain physiographic region. Since only the Highland analysis resulted in a threshold value (1%), this threshold was applied to all sites. Applying the threshold to individual sites will allow the determination of the *high % of barren land in watershed* condition considered for the BSID.

Barren Land in 60m Stream Buffer

This measure represents the proportion of exposed rock, clay, sand, surface mining activities, etc within 60 meters of streams upstream from sample stations. Streams below barren areas, particularly in close proximity, could potentially experience altered flow regimes and increased sediment loads.

Barren land within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results.

A threshold value indicating potentially significant biological degradation was identified for one region, Highland (1%) (see Appendix A: Table A-26). No statistically significant barren land 60m stream buffer threshold values were determined for the Eastern Piedmont and Coastal Plain physiographic region. Since only the Highland analysis resulted in a threshold value (1%), this threshold was applied to all sites. Applying the threshold to individual sites will allow the determination of the *high % of barren land 60m stream buffer* condition considered for the BSID.

4.2.4 Anthropogenic Land Use

Forest Land in Watershed

The amount of forested land reveals the general extent of urban and agricultural development within a watershed. Forested land use is natural areas dominated by tree cover with an understory of natural plant material or ground cover. Due to processes such as evaporation, water uptake, and transpiration, watersheds with high forest proportions demonstrate natural hydrological regimes. High forest proportions also suggest that erosion will be limited due to canopies that reduce the impact of heavy rain events, along with roots and leaf litter that secure soils from transport in any overland water flow. Due to the retention of precipitation by living vegetation and leaf litter, less surface water flow will means less chance for transport of pollutants (e.g., nutrients, organic, and inorganic contaminants). High forest proportion also suggests that heterotrophic material will be in abundance, and that autochthonous production will be minimal due to the presence of canopies over small water bodies. Thus, decreased amounts of forested land use within a watershed will affect hydrological regimes, nutrient loads, trophic conditions, and inorganic pollutant contaminants on surface waters.

Forested land use threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results. Proportions below the threshold percentages may indicate biological degradation.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-27). Based on results, thresholds were set for the three regions at 25% (Highland), 15% (Eastern Piedmont), and 15% (Coastal Plain). Applying these thresholds value to individual sites allows the determination of the *low % of forested land in watershed* condition considered for the BSID.

Forest Land in 60m Stream Buffer

This measure represents the proportion forested land use within 60 meters of streams upstream from sample stations. Low forest riparian proportions should associate with higher anthropogenic disturbances and pollutant loadings to surface waters. Riparian zones serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee et al. 2004).

Forested land within 60m stream buffer threshold values are determined by comparing the 90th percentile concentration among very poor, poor, fair, and good biological conditions (fish and benthic separately). The comparison is made statewide and also separately for the Highland, Eastern Piedmont and Coastal Plain physiographic regions. Threshold values, indicating biological degradation, are set by determining if there is a statistically significant difference between the poor and fair group, and then between the very poor and good group of sites. A final threshold value is set based on review of the results. Proportions below the threshold percentages may indicate biological degradation.

Threshold values indicating potentially significant biological degradation were identified for the state and all three regions (see Appendix A: Table A-28). Based on results, thresholds were set for the three regions at 35% (Highland), 35% (Eastern piedmont), and 30% (Coastal plain). Applying these threshold values to individual sites allows the determination of the *low % of forested land 60m stream buffer* condition considered for the BSID.

4.2.5 Sources of Acidity - Atmospheric Deposition

Acidity is a problematic aspect of atmospheric deposition, with the pH of rain often in the range of 3.5 to 5.0. Acidic deposition is the contribution of material from atmospheric sources, both as wet precipitation (wet) and particulate (dry) deposition. Atmospheric deposition is generally associated with elevated concentrations of sulfates and nitrates. Atmospheric deposition reflects a binary response (i.e., yes/no) for presence in a watershed and is contained in the principal dataset. The condition considered for the BSID analysis is *atmospheric deposition present.*

4.2.6 Sources of Acidity - Acid Mine Drainage

Acid mine drainage (AMD) results from the oxidation of mineral pyrite, which is found in mine spoils and abandoned mine shafts, and is known to cause extreme acidification of surface waters as well as affect stream physical substrate. Streams strongly affected by AMD exhibit high levels of sulfate, manganese, iron, aluminum, and conductivity. Highly acidic waters (pH < 3) can solubilise heavy metals and other toxic elements from soil and cause them to be transported into nearby surface waters. The high acidity of acid mine drainage and the high amounts of dissolved heavy metals (such as copper and zinc) generally make acid mine drainage extremely toxic to most organisms (Penreath, 1994). AMD reflects a binary response (i.e., yes/no) for presence in a watershed and is contained in the principal dataset. The condition considered for the BSID analysis is *AMD present.*

4.2.7 Sources of Acidity – Organic Acid Source

Natural decay of organic materials may contribute acidity in the form of organic anions, as in blackwater streams associated with bald cypress wetlands and boreal bogs. Streams dominated by organic sources are often characterized by high concentrations of dissolved organic carbon (DOC > 8 mg/L) and organic anions. Organic acid source reflect a binary response (i.e., yes/no) for presence in a watershed and is contained in the principal dataset. The condition considered for the BSID analysis is *organic acid source present.*

4.2.8 Sources of Acidity – Agricultural Acid Source

Agricultural lands fertilized with high levels of nitrogen, or other acidifying compounds are a source of acidification in surface waters. Agricultural activities in watersheds effect stream chemistry, adding both ANC, from soil liming practices, and strong acid anions from nitrogen fertilizers. Agricultural acid source reflect a binary response (i.e., yes/no) for presence in a watershed and is contained in the principal dataset. The condition considered for the BSID analysis is *agricultural acid source present.*

5. Statistical Methods

MDE has adopted a case-control, risk-based approach to identify and support the stressors and sources of biological impairments. The BSID analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group. The case group is defined as the sites within the assessment unit with degraded biological conditions and the controls are sites with similar physiographic characteristics that have good biological conditions. In Maryland three physiographic eco-regions were identified from the MDDNR MBSS index of biotic integrity (IBI) metrics: Highland, Eastern Piedmont, and Coastal (Southerland et al. 2005b).

Measures of association statistics are applied to assess the influence of stressors on degraded biological conditions. It was determined that, given the binary structure (i.e., present/absent, yes/no) of the biological response and stressor/source data, the most appropriate statistical method was to report the data in a 2-way contingency table and evaluate the strength of association using the odds ratio. Table 2 provides an example of a 2-way contingency table.

Table 2. Example 2-way Contingency Table

	Degraded Cases (Sites with very poor to poor biological communities in assessment unit)	Controls (Sites with fair to good biological communities in similar physiographic region)	Total
Stressor/Source Present	a	b	m_1
Stressor/Source Absent	c	d	m_0
Total	n_1	n_0	n

where,

a = # of sites with very poor to poor biological condition and stressor/source present
b = # of sites with fair to good biological condition and stressor/source present
c = # of sites with poor to very poor biological condition and stressor/source absent
d = # of sites with fair to good biological condition and stressor/source absent
n_1 = Total # of cases
n_0 = Total # of controls
m_1 = Total # of case and control sites with stressor present
m_0 = Total # of case and control sites with stressor absent
n = Total # of case and control sites

The odds ratio is calculated as

Odds Ratio = $\frac{a}{b}\Big/\frac{c}{d}$, which is also equivalent to $\frac{a}{c}\Big/\frac{b}{d}$ and $\frac{ad}{cb}$

When case sites span multiple geographic strata it is important to compare cases with controls from the appropriate strata. In this scenario a common odds ratio is calculated by developing a separate 2x2 table for each physiographic region. The combined or common odds ratio is then calculated using the Mantel-Haenszel (MH) approach. The MH odds ratio is calculated as follows:

$$\text{Odds Ratio}_{MH} = \left. \sum_{g=1}^{G} \frac{a_g d_g}{n_g} \middle/ \sum_{g=1}^{G} \frac{b_g c_g}{n_g} \right.$$

Where

Odds Ratio_{MH} = the Mantel-Haenszel common odds ratio
g = identifier used to denote the stratum
G = the total number of strata

In addition to the three physiographic strata defined by the BIBI, habitat parameters were also grouped into two additional strata defined by sites in first order streams and sites in second through fourth order streams. The rationale for this was that the extent or quality of habitat can vary naturally with stream order and it is more appropriate to compare streams of similar size. The division of these two stream order strata resulted in approximately equal number of control sites per strata. Also, due to sample size limitations, the second through fourth order streams were not subdivided into small groups.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the MH (1959) approach and based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are poor to very poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and poor to very poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e. cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are a result of the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present. The equation is as follows.

$$AR = R_{cases} - R_{controls}$$

where

AR = attributable risk
R_{cases} = absolute risk (proportion) of stressor among cases
$R_{controls}$ = absolute risk (proportion) of stressor among controls

When multiple strata are present and the data are from a case control study, Bruzzi et al. (1985) stated that the AR can be estimated using the cases alone once the relative risk is known. Instead of using the relative risk, it is possible to sum the AR for each case over all the cases. The assumption is that each case site has its own absolute risk. If the stressor is present the absolute risk is unity whereas if the stressor is absent the absolute risk is zero. The absolute risk of the stressor among the controls, for the specific case site, is determined based on the physiographic region of the case site and includes stream order if the stressor is related to habitat condition. The following equation is used to determine the AR when considering multiple strata:

$$AR = \frac{\sum_{g=1}^{G} \sum_{i=1}^{n_{ig}} \left[Rcase_{ig} - Rcontrols_{g} \right]}{G \cdot n_g}$$

where

AR = Attributable risk for a population of sites within a watershed
$Rcase_{ig}$ = absolute risk of stressor for case i in stratum g (0 or 1)
$Rcontrols_g$ = absolute risk of stressor among controls for stratum g
G = total number of strata
n_g = number of cases within stratum g
$G \cdot n_g$ = total number of cases

Once the AR is defined for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls. For example, if high embeddedness and poor epifaunal substrate were present at the site and the absolute risk among the controls were 0.25 and 0.15 respectively, then a value of 0.15 would be used since it has the lowest risk among the controls and would produce the highest AR. The equation for estimating AR for groups of stressors is as follows:

$$AR = \frac{\sum_{g=1}^{G} \sum_{i=1}^{n_{ig}} \max_j \left[Rcase_{jig} - Rcontrols_{jg} \right]}{G \cdot n_g}$$

where

AR = Attributable risk for a population of sites within a watershed
$Rcase_{jig}$ = absolute risk of stressor j for case i in stratum g (0 or 1)
$Rcontrols_{jg}$ = absolute risk of stressor j among controls for stratum g
G = total number of strata
n_g = number of cases within stratum g
$G \cdot n_g$ = total number of cases

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated. The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases. While there is not a reported acceptable value for this metric, it is recommended that a limit be selected based on the number of cases in the watershed and consideration for the biological listing methodology.

To assist in determining potential sources of the stressors, the above described statistical methods are applied to all source parameters (e.g. land use, AMD, etc.).

6. Conclusion

The BSID process will use results from the BSID analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID analysis results is based upon components of Hill's Postulates (1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

BSID process uses general causal scenarios to aide in the interpretation of how land-use conditions might generate in-stream stressors and how the resulting impacts can alter the biological community and structure. Appendix B contains four general causal scenario models MDE uses to aide in the interpretation of results from the BSID analysis. With the general understanding of ecological processes within casual scenarios and knowledge of impaired watersheds, MDE can determine likely causes of degraded biological conditions.

Ecologically plausible causal models will be developed specifically for a watershed based on BSID analysis results. Once the BSID analysis is completed and a final causal model is developed, a number of stressors (pollutants) may be identified as the cause of the poor to very poor biological condition within the Maryland 8-digit watershed. If there are multiple stressors (pollutants) then the process will evaluate the AR for each stressor and rank them appropriately.

Finally, water quality limited segments with degraded biological condition caused by specific stressor(s) (e.g., sediment, nutrients) are compared to the current Integrated Report listing categories for the 8 digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

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Appendix A

Table A-1 Statewide and Physiographic Eco-region Analysis for Embeddedness

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	100 (97,100)	174
Poor (2-3)	100 (100,100)	286
Fair (3-4)	100 (100,100)	292
Good (4-5)	100 (90,100)	322
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	100 (100,100)	110
Poor (2-3)	100 (100,100)	173
Fair (3-4)	100 (90,100)	291
Good (4-5)	100 (100,100)	317
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	85 (80,90)	56
Poor (2-3)	65 (57,75)	107
Fair (3-4)	49 (45,50)	103
Good (4-5)	35 (35,40)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	49
Very Poor vs. Good	Yes	57

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	86 (75,90)	39
Poor (2-3)	65 (55,80)	66
Fair (3-4)	55 (49.5,65)	92
Good (4-5)	40 (40,45)	101
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	60

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	55.4 (50.2,61)	79
Poor (2-3)	78 (54,90)	73
Fair (3-4)	55 (45,60)	68
Good (4-5)	40 (39.6,45)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	66.5

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	57 (50,90)	31
Poor (2-3)	45.5 (40.5,50.5)	40
Fair (3-4)	55 (50,60)	95
Good (4-5)	40 (38.9,45)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	50.25

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	100 (100,100)	39
Poor (2-3)	100 (100,100)	106
Fair (3-4)	100 (100,100)	121
Good (4-5)	100 (100,100)	121
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	100 (100,100)	40
Poor (2-3)	100 (100,100)	67
Fair (3-4)	100 (100,100)	104
Good (4-5)	100 (100,100)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-2 Statewide and Physiographic Eco-region Analysis for Bank Stability Index

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	6.3 (5.1,10.0)	175
Poor (2-3)	8.0 (7.0,8.9)	286
Fair (3-4)	8.3 (7.3,9.2)	293
Good (4-5)	7.0 (6.3,8.3)	322
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	7.9 (5.0,9.9)	110
Poor (2-3)	6.6 (5.3,9.0)	173
Fair (3-4)	7.0 (6.4,8.3)	291
Good (4-5)	8.3 (7.0,9.0)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8.8 (5.0,10.5)	56
Poor (2-3)	7.0 (6.0,8.8)	107
Fair (3-4)	11.7 (9.2,13.0)	104
Good (4-5)	14.7 (14.1,16.0)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	11.7
Very Poor vs. Good	Yes	9.4

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9.6 (5.0,12.0)	39
Poor (2-3)	8.8 (6.3,11.5)	66
Fair (3-4)	8.2 (7.0,10.0)	92
Good (4-5)	10.0 (8.9,12.1)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	7.7 (5.2,11.8)	79
Poor (2-3)	8.1 (5.8,9.5)	73
Fair (3-4)	7.7 (6.2,9.6)	68
Good (4-5)	7.8 (6.3,8.5)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8.3 (7.5,13.3)	31
Poor (2-3)	5.0 (4.9,6.2)	40
Fair (3-4)	8.2 (6.5,9.7)	95
Good (4-5)	8.7 (6.7,9.9)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	6.4
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5.5 (3.1,12.3)	40
Poor (2-3)	9.2 (7.3,10.5)	106
Fair (3-4)	6.8 (5.0,9.0)	121
Good (4-5)	5.0 (3.5,6.5)	121
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	3.4 (2.0,10.3)	40
Poor (2-3)	9.2 (7.3,10.4)	67
Fair (3-4)	5.7 (3.5,8.0)	104
Good (4-5)	6.2 (5.5,7.2)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-3 Statewide and Physiographic Eco-region Analysis for Riparian Buffer Width

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	182
Poor (2-3)	0.0 (0.0,0.0)	300
Fair (3-4)	0.0 (0.0,0.0)	306
Good (4-5)	0.0 (0.0,0.0)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	110
Poor (2-3)	0.0 (0.0,0.0)	172
Fair (3-4)	0.0 (0.0,0.0)	290
Good (4-5)	0.0 (0.0,0.0)	313
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	57
Poor (2-3)	0.0 (0.0,0.0)	115
Fair (3-4)	0.0 (0.0,0.0)	110
Good (4-5)	0.0 (0.0,0.0)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	39
Poor (2-3)	0.0 (0.0,0.0)	66
Fair (3-4)	0.0 (0.0,0.0)	92
Good (4-5)	0.0 (0.0,0.0)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	80
Poor (2-3)	0.0 (0.0,0.0)	74
Fair (3-4)	0.0 (0.0,0.0)	69
Good (4-5)	0.0 (0.0,0.0)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	31
Poor (2-3)	0.0 (0.0,0.0)	40
Fair (3-4)	0.0 (0.0,0.0)	95
Good (4-5)	0.0 (0.0,0.0)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	45
Poor (2-3)	0.0 (0.0,0.0)	111
Fair (3-4)	0.0 (0.0,14.6)	127
Good (4-5)	28.6 (0.0,35.0)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.0 (0.0,0.0)	40
Poor (2-3)	0.0 (0.0,0.0)	66
Fair (3-4)	0.0 (0.0,20.0)	103
Good (4-5)	0.0 (0.0,27.4)	99
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-4 Statewide and Physiographic Eco-region Analysis for Shading

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	30 (20,45)	174
Poor (2-3)	45 (40,60)	286
Fair (3-4)	50 (45,60)	293
Good (4-5)	57.3 (45.5,60.3)	322
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	47.5

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	65 (60,65)	110
Poor (2-3)	47 (40,60)	173
Fair (3-4)	50 (40,60)	291
Good (4-5)	40 (35,45)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	27.5 (20,37.5)	56
Poor (2-3)	38 (25.30098272,54)	107
Fair (3-4)	45 (45,60)	104
Good (4-5)	40 (37.5,56)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	65 (34,69)	39
Poor (2-3)	35 (25,45)	66
Fair (3-4)	45 (35,60)	92
Good (4-5)	40 (35,40.5)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	62.4 (60,65)	79
Poor (2-3)	60 (47,65)	73
Fair (3-4)	65 (35,70)	68
Good (4-5)	60 (50,62)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	63.33333333 (30,70)	31
Poor (2-3)	60 (55.5,69.5)	40
Fair (3-4)	60 (52,65)	95
Good (4-5)	46 (35.3,60.3)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	16.6 (6.8,42)	39
Poor (2-3)	55 (35,65)	106
Fair (3-4)	55 (30,65)	121
Good (4-5)	65 (63,75)	121
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	55

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	74.5 (64.5,85)	40
Poor (2-3)	73 (56,78)	67
Fair (3-4)	40 (30,65)	104
Good (4-5)	42.1 (25,57.4)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-5 Statewide and Physiographic Eco-region Analysis for Total Phosphorous

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.10 (0.09,0.12)	182
Poor (2-3)	0.11 (0.10,0.13)	300
Fair (3-4)	0.09 (0.08,0.10)	307
Good (4-5)	0.06 (0.05,0.07)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	0.09
Very Poor vs. Good	Yes	0.10

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.10 (0.08,0.11)	110
Poor (2-3)	0.10 (0.08,0.11)	172
Fair (3-4)	0.09 (0.08,0.10)	290
Good (4-5)	0.07 (0.06,0.07)	313
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.09

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.09 (0.07,0.14)	57
Poor (2-3)	0.08 (0.06,0.10)	115
Fair (3-4)	0.05 (0.03,0.06)	110
Good (4-5)	0.02 (0.02,0.02)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.06

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.07 (0.05,0.09)	39
Poor (2-3)	0.07 (0.05,0.10)	66
Fair (3-4)	0.06 (0.04,0.06)	92
Good (4-5)	0.03 (0.03,0.04)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.06

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.06 (0.05,0.09)	80
Poor (2-3)	0.07 (0.05,0.13)	74
Fair (3-4)	0.05 (0.04,0.08)	69
Good (4-5)	0.04 (0.04,0.05)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.06

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.06 (0.04,0.07)	31
Poor (2-3)	0.04 (0.03,0.05)	40
Fair (3-4)	0.04 (0.03,0.06)	95
Good (4-5)	0.05 (0.05,0.07)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.14 (0.11,0.17)	45
Poor (2-3)	0.16 (0.12,0.19)	111
Fair (3-4)	0.11 (0.10,0.13)	128
Good (4-5)	0.09 (0.08,0.09)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.14

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.12 (0.10,0.14)	40
Poor (2-3)	0.12 (0.10,0.18)	66
Fair (3-4)	0.13 (0.10,0.16)	103
Good (4-5)	0.10 (0.08,0.11)	99
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-6 Statewide and Physiographic Eco-region Analysis for Ortho Phosphate

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.03 (0.02,0.04)	182
Poor (2-3)	0.03 (0.03,0.04)	300
Fair (3-4)	0.02 (0.01,0.02)	307
Good (4-5)	0.02 (0.01,0.02)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	0.02
Very Poor vs. Good	Yes	0.02

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.02 (0.01,0.04)	110
Poor (2-3)	0.02 (0.02,0.03)	172
Fair (3-4)	0.02 (0.01,0.03)	290
Good (4-5)	0.02 (0.02,0.02)	313
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.04 (0.02,0.07)	57
Poor (2-3)	0.03 (0.02,0.04)	115
Fair (3-4)	0.01 (0.01,0.02)	110
Good (4-5)	0.01 (0.01,0.01)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	0.01
Very Poor vs. Good	Yes	0.02

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.02 (0.01,0.06)	39
Poor (2-3)	0.02 (0.02,0.03)	66
Fair (3-4)	0.02 (0.01,0.03)	92
Good (4-5)	0.01 (0.01,0.01)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.02

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.01 (0.01,0.02)	80
Poor (2-3)	0.03 (0.01,0.04)	74
Fair (3-4)	0.02 (0.01,0.02)	69
Good (4-5)	0.02 (0.01,0.02)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.01 (0.01,0.04)	31
Poor (2-3)	0.01 (0.01,0.02)	40
Fair (3-4)	0.01 (0.01,0.02)	95
Good (4-5)	0.02 (0.02,0.03)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.04 (0.03,0.05)	45
Poor (2-3)	0.04 (0.02,0.04)	111
Fair (3-4)	0.02 (0.02,0.03)	128
Good (4-5)	0.02 (0.02,0.03)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.03 (0.01,0.04)	40
Poor (2-3)	0.04 (0.02,0.06)	66
Fair (3-4)	0.03 (0.02,0.04)	103
Good (4-5)	0.03 (0.02,0.03)	99
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-7 Statewide and Physiographic Eco-region Analysis for Total Nitrogen

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5.44 (4.53,5.92)	182
Poor (2-3)	4.99 (4.63,5.50)	300
Fair (3-4)	4.68 (4.35,4.87)	307
Good (4-5)	4.80 (4.37,5.05)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5.91 (4.60,6.07)	110
Poor (2-3)	4.61 (4.08,4.98)	172
Fair (3-4)	4.69 (4.38,4.76)	290
Good (4-5)	5.22 (4.83,5.52)	313
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	7.35 (5.93,8.83)	57
Poor (2-3)	4.72 (4.46,4.98)	115
Fair (3-4)	2.96 (2.64,4.23)	110
Good (4-5)	1.68 (1.47,1.80)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	2.96
Very Poor vs. Good	Yes	3.84

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	6.52 (5.57,8.68)	39
Poor (2-3)	4.40 (3.54,4.94)	66
Fair (3-4)	4.43 (4.04,4.69)	92
Good (4-5)	3.01 (2.77,3.76)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	4.42

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	3.26 (2.92,4.45)	80
Poor (2-3)	4.75 (3.88,5.85)	74
Fair (3-4)	5.13 (4.40,5.90)	69
Good (4-5)	5.08 (4.77,5.49)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5.91 (4.55,6.04)	31
Poor (2-3)	3.54 (2.99,4.90)	40
Fair (3-4)	4.14 (3.99,4.69)	95
Good (4-5)	5.27 (4.84,5.77)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	3.64 (2.45,4.29)	45
Poor (2-3)	6.18 (4.66,7.02)	111
Fair (3-4)	4.80 (4.53,5.51)	128
Good (4-5)	5.31 (4.77,5.89)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1.70 (1.39,1.85)	40
Poor (2-3)	5.38 (3.96,6.28)	66
Fair (3-4)	5.81 (4.71,7.22)	103
Good (4-5)	6.01 (5.28,6.97)	99
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-8 Statewide and Physiographic Eco-region Analysis for Total Dissolved Nitrogen

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	3.97 (2.94,7.40)	39
Poor (2-3)	4.74 (4.29,5.42)	52
Fair (3-4)	4.38 (3.62,4.68)	70
Good (4-5)	4.64 (3.96,5.14)	100
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5.77 (1.66,6.97)	22
Poor (2-3)	3.58 (2.36,4.85)	28
Fair (3-4)	4.52 (3.84,4.65)	75
Good (4-5)	4.95 (4.29,5.41)	96
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8.05 (4.02,9.90)	16
Poor (2-3)	3.65 (2.57,4.34)	22
Fair (3-4)	2.74 (1.79,3.44)	29
Good (4-5)	1.17 (0.76,2.12)	28
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	3.20

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	6.97 (1.55,9.12)	11
Poor (2-3)	1.65 (1.26,3.01)	13
Fair (3-4)	4.57 (3.67,6.62)	24
Good (4-5)	2.50 (1.88,2.80)	33
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	2.02 (1.65,3.08)	13
Poor (2-3)	6.02 (4.41,6.28)	17
Fair (3-4)	4.73 (4.38,6.21)	21
Good (4-5)	5.15 (4.35,5.65)	40
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	4.30 (1.50,6.11)	5
Poor (2-3)	4.95 (4.13,5.03)	5
Fair (3-4)	4.02 (3.48,4.73)	28
Good (4-5)	5.82 (5.23,6.25)	40
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1.43 (1.22,2.01)	10
Poor (2-3)	4.73 (3.66,5.29)	13
Fair (3-4)	3.67 (2.03,4.43)	20
Good (4-5)	4.60 (3.41,5.24)	32
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1.26 (0.62,1.70)	6
Poor (2-3)	2.27 (1.29,4.15)	10
Fair (3-4)	4.43 (2.76,4.64)	23
Good (4-5)	4.63 (4.10,5.31)	23
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-9 Statewide and Physiographic Eco-region Analysis for Chlorides

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	148.4 (113.5,158.9)	181
Poor (2-3)	77.3 (73.1,84.4)	300
Fair (3-4)	49.0 (45.3,58.9)	307
Good (4-5)	30.4 (28.1,32.6)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	49.0
Very Poor vs. Good	Yes	63.1

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	99.1 (82.5,122.0)	109
Poor (2-3)	106.6 (85.6,144.2)	172
Fair (3-4)	61.1 (56.5,68.3)	290
Good (4-5)	55.2 (47.2,62.9)	313
Group	Significant	Target Value
Poor vs. Fair	Yes	61.1
Very Poor vs. Good	Yes	83.9

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	90.7 (71.7,113.5)	57
Poor (2-3)	64.0 (54.8,70.9)	115
Fair (3-4)	50.5 (38.5,77.8)	110
Good (4-5)	14.6 (12.7,27.5)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	57.2

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	60.9 (55.5,73.6)	39
Poor (2-3)	126.1 (77.7,174.2)	66
Fair (3-4)	49.1 (46.2,67.6)	92
Good (4-5)	60.2 (45.9,71.7)	102
Group	Significant	Target Value
Poor vs. Fair	Yes	49.1
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	152.4 (141.4,179.2)	80
Poor (2-3)	92.6 (84.3,137.1)	74
Fair (3-4)	48.2 (38.4,68.8)	69
Good (4-5)	33.0 (31.3,39.8)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	48.2
Very Poor vs. Good	Yes	70.4

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	141.3 (119.3,190.4)	31
Poor (2-3)	144.5 (82.5,160.5)	40
Fair (3-4)	75.5 (64.6,86.8)	95
Good (4-5)	55.2 (46.9,67.2)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	110.0

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	143.6 (93.9,262.8)	44
Poor (2-3)	71.0 (65.4,87.2)	111
Fair (3-4)	47.6 (42.2,54.7)	128
Good (4-5)	27.8 (24.8,30.9)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	47.6
Very Poor vs. Good	Yes	59.3

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	68.1 (59.6,76.1)	39
Poor (2-3)	83.0 (53.9,103.1)	66
Fair (3-4)	55.9 (40.7,59.8)	103
Good (4-5)	47.4 (37.0,57.7)	99
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	69.5

Table A-10 Statewide and Physiographic Eco-region Analysis for Conductivity

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.772 (0.748,0.861)	182
Poor (2-3)	0.560 (0.496,0.577)	300
Fair (3-4)	0.311 (0.290,0.349)	307
Good (4-5)	0.220 (0.207,0.240)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	0.311
Very Poor vs. Good	Yes	0.435

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.708 (0.634,0.762)	110
Poor (2-3)	0.656 (0.578,0.731)	172
Fair (3-4)	0.450 (0.411,0.491)	290
Good (4-5)	0.347 (0.317,0.381)	313
Group	Significant	Target Value
Poor vs. Fair	Yes	0.450
Very Poor vs. Good	Yes	0.553

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.773 (0.735,0.805)	57
Poor (2-3)	0.595 (0.513,0.645)	115
Fair (3-4)	0.406 (0.300,0.519)	110
Good (4-5)	0.183 (0.149,0.220)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.501

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.751 (0.627,0.778)	39
Poor (2-3)	0.770 (0.648,0.795)	66
Fair (3-4)	0.566 (0.481,0.606)	92
Good (4-5)	0.402 (0.340,0.504)	102
Group	Significant	Target Value
Poor vs. Fair	Yes	0.566
Very Poor vs. Good	Yes	0.668

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.758 (0.703,0.894)	80
Poor (2-3)	0.623 (0.506,0.723)	74
Fair (3-4)	0.314 (0.293,0.369)	69
Good (4-5)	0.238 (0.216,0.266)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	0.314
Very Poor vs. Good	Yes	0.469

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.708 (0.690,0.938)	31
Poor (2-3)	0.711 (0.523,0.795)	40
Fair (3-4)	0.477 (0.398,0.504)	95
Good (4-5)	0.342 (0.308,0.385)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	0.477
Very Poor vs. Good	Yes	0.594

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.853 (0.616,1.390)	45
Poor (2-3)	0.415 (0.375,0.495)	111
Fair (3-4)	0.271 (0.260,0.308)	128
Good (4-5)	0.209 (0.192,0.243)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	0.271
Very Poor vs. Good	Yes	0.343

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0.408 (0.366,0.693)	40
Poor (2-3)	0.511 (0.350,0.571)	66
Fair (3-4)	0.314 (0.270,0.363)	103
Good (4-5)	0.270 (0.247,0.350)	99
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	0.412

Table A-11 Statewide and Physiographic Eco-region Analysis for Sulfate

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	39.0 (35.6,42.0)	182
Poor (2-3)	33.8 (31.3,36.7)	300
Fair (3-4)	25.1 (24.3,26.1)	307
Good (4-5)	17.6 (17.1,19.1)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	25.1
Very Poor vs. Good	Yes	29.5

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	44.4 (37.4,48.8)	110
Poor (2-3)	35.8 (31.5,43.9)	172
Fair (3-4)	24.5 (23.4,25.9)	290
Good (4-5)	20.5 (19.0,23.2)	313
Group	Significant	Target Value
Poor vs. Fair	Yes	24.5
Very Poor vs. Good	Yes	30.1

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	72.1 (40.4,208.8)	57
Poor (2-3)	36.8 (29.4,57.1)	115
Fair (3-4)	25.2 (23.5,28.4)	110
Good (4-5)	21.2 (17.0,31.3)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	25.2
Very Poor vs. Good	Yes	31.0

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	83.4 (45.9,108.6)	39
Poor (2-3)	59.9 (44.9,90.9)	66
Fair (3-4)	26.6 (24.5,30.4)	92
Good (4-5)	24.1 (20.0,25.8)	102
Group	Significant	Target Value
Poor vs. Fair	Yes	26.6
Very Poor vs. Good	Yes	43.3

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	33.5 (28.0,34.6)	80
Poor (2-3)	23.5 (19.9,27.0)	74
Fair (3-4)	13.7 (13.1,24.3)	69
Good (4-5)	11.9 (11.1,15.5)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	18.6

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	35.0 (33.5,42.0)	31
Poor (2-3)	25.4 (21.3,29.9)	40
Fair (3-4)	19.4 (15.2,22.0)	95
Good (4-5)	14.0 (13.7,17.1)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	22.4

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	39.0 (34.5,48.2)	45
Poor (2-3)	37.1 (33.4,48.3)	111
Fair (3-4)	26.2 (24.8,27.3)	128
Good (4-5)	18.9 (17.5,22.8)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	26.2
Very Poor vs. Good	Yes	31.7

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	37.9 (29.9,47.5)	40
Poor (2-3)	32.9 (27.4,35.1)	66
Fair (3-4)	24.6 (22.3,27.3)	103
Good (4-5)	23.6 (20.8,26.0)	99
Group	Significant	Target Value
Poor vs. Fair	Yes	24.6
Very Poor vs. Good	Yes	28.8

Table A-12 Statewide and Physiographic Eco-region Analysis for Impervious Surface Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	21% (20%,23%)	181
Poor (2-3)	14% (12%,17%)	300
Fair (3-4)	4% (4%,6%)	303
Good (4-5)	3% (2%,3%)	324
Group	Significant	Target Value
Poor vs. Fair	Yes	4%
Very Poor vs. Good	Yes	9%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	20% (18%,21%)	110
Poor (2-3)	18% (15%,21%)	173
Fair (3-4)	8% (6%,11%)	287
Good (4-5)	6% (4%,6%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	8%
Very Poor vs. Good	Yes	13%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5% (4%,6%)	57
Poor (2-3)	4% (3%,6%)	115
Fair (3-4)	1% (1%,2%)	107
Good (4-5)	0% (0%,0%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	1%
Very Poor vs. Good	Yes	3%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	4% (3%,6%)	39
Poor (2-3)	4% (3%,5%)	66
Fair (3-4)	2% (1%,3%)	90
Good (4-5)	2% (1%,3%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	23% (21%,24%)	80
Poor (2-3)	18% (15%,20%)	74
Fair (3-4)	4% (3%,5%)	69
Good (4-5)	1% (1%,2%)	114
Group	Significant	Target Value
Poor vs. Fair	Yes	4%
Very Poor vs. Good	Yes	11%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	24% (20%,26%)	31
Poor (2-3)	27% (19%,29%)	40
Fair (3-4)	11% (9%,13%)	94
Good (4-5)	5% (4%,6%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	11%
Very Poor vs. Good	Yes	19%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	23% (20%,24%)	44
Poor (2-3)	21% (15%,23%)	111
Fair (3-4)	8% (6%,10%)	127
Good (4-5)	4% (3%,6%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	8%
Very Poor vs. Good	Yes	14%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	20% (15%,21%)	40
Poor (2-3)	20% (15%,25%)	67
Fair (3-4)	13% (7%,14%)	103
Good (4-5)	9% (7%,13%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	13%
Very Poor vs. Good	Yes	17%

Table A-13 Statewide and Physiographic Eco-region Analysis for High Intensity Urban Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	27% (25%,32%)	182
Poor (2-3)	21% (20%,24%)	300
Fair (3-4)	9% (8%,10%)	306
Good (4-5)	6% (6%,6%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	9%
Very Poor vs. Good	Yes	15%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	27% (23%,34%)	110
Poor (2-3)	23% (20%,25%)	173
Fair (3-4)	15% (12%,16%)	291
Good (4-5)	11% (9%,13%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	15%
Very Poor vs. Good	Yes	19%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	12% (10%,14%)	57
Poor (2-3)	11% (9%,13%)	115
Fair (3-4)	6% (5%,6%)	110
Good (4-5)	3% (2%,4%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	Yes	9%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	10% (9%,11%)	39
Poor (2-3)	9% (8%,12%)	66
Fair (3-4)	8% (7%,9%)	92
Good (4-5)	7% (6%,9%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	33% (27%,36%)	80
Poor (2-3)	27% (23%,29%)	74
Fair (3-4)	10% (9%,12%)	69
Good (4-5)	7% (6%,8%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	10%
Very Poor vs. Good	Yes	18%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	46% (27%,48%)	31
Poor (2-3)	30% (25%,36%)	40
Fair (3-4)	18% (15%,19%)	95
Good (4-5)	12% (10%,14%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	18%
Very Poor vs. Good	Yes	24%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	32% (25%,34%)	45
Poor (2-3)	27% (21%,33%)	111
Fair (3-4)	11% (8%,13%)	127
Good (4-5)	7% (6%,8%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	11%
Very Poor vs. Good	Yes	19%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	31% (20%,35%)	40
Poor (2-3)	25% (20%,33%)	67
Fair (3-4)	15% (12%,19%)	104
Good (4-5)	14% (10%,17%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	15%
Very Poor vs. Good	Yes	20%

Table A-14 Statewide and Physiographic Eco-region Analysis for High Intensity Urban Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	23% (19%,28%)	180
Poor (2-3)	13% (12%,15%)	299
Fair (3-4)	6% (6%,7%)	303
Good (4-5)	4% (4%,5%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	Yes	10%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	18% (16%,21%)	109
Poor (2-3)	13% (12%,19%)	173
Fair (3-4)	8% (7%,9%)	291
Good (4-5)	7% (6%,7%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	8%
Very Poor vs. Good	Yes	11%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	19% (15%,26%)	56
Poor (2-3)	8% (8%,9%)	115
Fair (3-4)	6% (5%,7%)	110
Good (4-5)	5% (4%,5%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	Yes	7%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	14% (7%,15%)	39
Poor (2-3)	12% (8%,16%)	66
Fair (3-4)	6% (5%,7%)	92
Good (4-5)	7% (6%,8%)	102
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	25% (19%,33%)	80
Poor (2-3)	18% (14%,27%)	74
Fair (3-4)	6% (4%,7%)	68
Good (4-5)	4% (4%,5%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	Yes	12%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	40% (19%,50%)	31
Poor (2-3)	19% (13%,24%)	40
Fair (3-4)	12% (9%,14%)	95
Good (4-5)	6% (5%,7%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	15%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	25% (20%,31%)	44
Poor (2-3)	13% (10%,16%)	110
Fair (3-4)	7% (5%,9%)	125
Good (4-5)	3% (3%,5%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	7%
Very Poor vs. Good	Yes	10%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	13% (6%,21%)	39
Poor (2-3)	13% (12%,21%)	67
Fair (3-4)	6% (4%,9%)	104
Good (4-5)	7% (6%,9%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	No	NA

Table A-15 Statewide and Physiographic Eco-region Analysis for Low Intensity Urban Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	74% (71%,76%)	182
Poor (2-3)	60% (59%,62%)	300
Fair (3-4)	44% (40%,49%)	306
Good (4-5)	32% (28%,35%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	44%
Very Poor vs. Good	Yes	52%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	71% (67%,74%)	110
Poor (2-3)	64% (61%,72%)	173
Fair (3-4)	53% (50%,57%)	291
Good (4-5)	42% (39%,48%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	53%
Very Poor vs. Good	Yes	58%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	42% (33%,56%)	57
Poor (2-3)	35% (30%,52%)	115
Fair (3-4)	19% (17%,28%)	110
Good (4-5)	13% (10%,18%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	19%
Very Poor vs. Good	Yes	27%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	25% (19%,28%)	39
Poor (2-3)	31% (27%,44%)	66
Fair (3-4)	33% (28%,41%)	92
Good (4-5)	25% (20%,30%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	79% (74%,82%)	80
Poor (2-3)	74% (67%,76%)	74
Fair (3-4)	52% (48%,58%)	69
Good (4-5)	35% (33%,40%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	52%
Very Poor vs. Good	Yes	63%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	82% (73%,85%)	31
Poor (2-3)	74% (73%,81%)	40
Fair (3-4)	61% (58%,63%)	95
Good (4-5)	46% (40%,51%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	61%
Very Poor vs. Good	Yes	68%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	68% (63%,73%)	45
Poor (2-3)	60% (53%,62%)	111
Fair (3-4)	50% (43%,57%)	127
Good (4-5)	33% (28%,35%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	55%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	67% (63%,74%)	40
Poor (2-3)	59% (50%,63%)	67
Fair (3-4)	52% (46%,59%)	104
Good (4-5)	47% (38%,51%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	56%

Table A-16 Statewide and Physiographic Eco-region Analysis for Low Intensity Urban Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	71% (68%,74%)	180
Poor (2-3)	63% (56%,66%)	299
Fair (3-4)	29% (26%,33%)	303
Good (4-5)	22% (19%,24%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	29%
Very Poor vs. Good	Yes	46%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	68% (62%,71%)	109
Poor (2-3)	70% (64%,73%)	173
Fair (3-4)	40% (38%,42%)	291
Good (4-5)	29% (26%,33%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	40%
Very Poor vs. Good	Yes	55%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	41% (36%,45%)	56
Poor (2-3)	41% (36%,45%)	115
Fair (3-4)	21% (17%,24%)	110
Good (4-5)	13% (11%,16%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	21%
Very Poor vs. Good	Yes	31%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	23% (18%,27%)	39
Poor (2-3)	41% (30%,58%)	66
Fair (3-4)	33% (25%,39%)	92
Good (4-5)	21% (18%,28%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	78% (72%,79%)	80
Poor (2-3)	80% (67%,87%)	74
Fair (3-4)	35% (28%,40%)	68
Good (4-5)	27% (23%,35%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	35%
Very Poor vs. Good	Yes	58%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	79% (70%,79%)	31
Poor (2-3)	78% (71%,84%)	40
Fair (3-4)	48% (40%,55%)	95
Good (4-5)	30% (26%,37%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	48%
Very Poor vs. Good	Yes	63%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	66% (60%,71%)	44
Poor (2-3)	65% (51%,68%)	110
Fair (3-4)	38% (28%,42%)	125
Good (4-5)	22% (18%,27%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	38%
Very Poor vs. Good	Yes	51%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	65% (57%,71%)	39
Poor (2-3)	67% (45%,79%)	67
Fair (3-4)	38% (31%,40%)	104
Good (4-5)	30% (26%,40%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	38%
Very Poor vs. Good	Yes	53%

Table A-17 Statewide and Physiographic Eco-region Analysis for Transportation Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	10% (9%,11%)	182
Poor (2-3)	9% (8%,9%)	300
Fair (3-4)	6% (5%,6%)	306
Good (4-5)	5% (4%,5%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	Yes	7%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9% (8%,10%)	110
Poor (2-3)	9% (8%,10%)	173
Fair (3-4)	7% (6%,7%)	291
Good (4-5)	6% (6%,6%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	7%
Very Poor vs. Good	Yes	8%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9% (8%,10%)	57
Poor (2-3)	7% (5%,7%)	115
Fair (3-4)	4% (4%,5%)	110
Good (4-5)	3% (2%,3%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	4%
Very Poor vs. Good	Yes	6%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8% (6%,9%)	39
Poor (2-3)	8% (6%,10%)	66
Fair (3-4)	5% (4%,5%)	92
Good (4-5)	5% (5%,6%)	102
Group	Significant	Target Value
Poor vs. Fair	Yes	5%
Very Poor vs. Good	Yes	6%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	11% (10%,12%)	80
Poor (2-3)	12% (9%,13%)	74
Fair (3-4)	7% (6%,8%)	69
Good (4-5)	6% (5%,7%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	7%
Very Poor vs. Good	Yes	9%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9% (8%,10%)	31
Poor (2-3)	11% (9%,12%)	40
Fair (3-4)	7% (7%,8%)	95
Good (4-5)	6% (6%,7%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	7%
Very Poor vs. Good	Yes	9%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9% (8%,10%)	45
Poor (2-3)	9% (8%,10%)	111
Fair (3-4)	6% (6%,7%)	127
Good (4-5)	4% (4%,5%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	6%
Very Poor vs. Good	Yes	8%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9% (6%,10%)	40
Poor (2-3)	7% (6%,9%)	67
Fair (3-4)	6% (5%,8%)	104
Good (4-5)	6% (5%,6%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-18 Statewide and Physiographic Eco-region Analysis for Transportation Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	13% (10%,16%)	180
Poor (2-3)	8% (6%,8%)	299
Fair (3-4)	4% (4%,5%)	303
Good (4-5)	4% (3%,4%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	4%
Very Poor vs. Good	Yes	6%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	10% (7%,12%)	109
Poor (2-3)	9% (8%,12%)	173
Fair (3-4)	5% (4%,6%)	291
Good (4-5)	5% (4%,5%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	5%
Very Poor vs. Good	Yes	7%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	18% (10%,21%)	56
Poor (2-3)	6% (6%,8%)	115
Fair (3-4)	6% (4%,7%)	110
Good (4-5)	4% (4%,5%)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	6%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	10% (7%,11%)	39
Poor (2-3)	9% (8%,15%)	66
Fair (3-4)	5% (4%,6%)	92
Good (4-5)	6% (5%,6%)	102
Group	Significant	Target Value
Poor vs. Fair	Yes	5%
Very Poor vs. Good	Yes	7%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	11% (9%,14%)	80
Poor (2-3)	12% (8%,14%)	74
Fair (3-4)	5% (3%,5%)	68
Good (4-5)	4% (3%,5%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	5%
Very Poor vs. Good	Yes	8%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	11% (7%,14%)	31
Poor (2-3)	10% (6%,12%)	40
Fair (3-4)	6% (5%,9%)	95
Good (4-5)	4% (4%,5%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	8%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	10% (4%,15%)	44
Poor (2-3)	6% (5%,7%)	110
Fair (3-4)	3% (3%,5%)	125
Good (4-5)	3% (2%,3%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	3%
Very Poor vs. Good	Yes	5%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5% (3%,13%)	39
Poor (2-3)	7% (5%,13%)	67
Fair (3-4)	3% (2%,3%)	104
Good (4-5)	4% (3%,4%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	3%
Very Poor vs. Good	No	NA

Table A-19 Statewide and Physiographic Eco-region Analysis for Agricultural Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	63% (53%,66%)	182
Poor (2-3)	64% (60%,65%)	300
Fair (3-4)	63% (61%,65%)	306
Good (4-5)	59% (56%,60%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	61% (45%,65%)	110
Poor (2-3)	59% (52%,60%)	173
Fair (3-4)	62% (59%,64%)	291
Good (4-5)	61% (59%,62%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	71% (67%,76%)	57
Poor (2-3)	60% (58%,64%)	115
Fair (3-4)	54% (49%,60%)	110
Good (4-5)	25% (22%,33%)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	57%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	67% (63%,71%)	39
Poor (2-3)	52% (45%,59%)	66
Fair (3-4)	57% (51%,60%)	92
Good (4-5)	54% (45%,58%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	55%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	35% (27%,39%)	80
Poor (2-3)	54% (49%,56%)	74
Fair (3-4)	63% (60%,65%)	69
Good (4-5)	62% (61%,64%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	29% (7%,41%)	31
Poor (2-3)	37% (31%,52%)	40
Fair (3-4)	60% (55%,62%)	95
Good (4-5)	62% (59%,62%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	51% (39%,57%)	45
Poor (2-3)	71% (64%,73%)	111
Fair (3-4)	68% (63%,72%)	127
Good (4-5)	58% (55%,61%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	49% (28%,62%)	40
Poor (2-3)	63% (58%,73%)	67
Fair (3-4)	67% (64%,71%)	104
Good (4-5)	63% (60%,71%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-20 Statewide and Physiographic Eco-region Analysis for Agricultural Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	54% (49%,68%)	180
Poor (2-3)	56% (52%,60%)	299
Fair (3-4)	46% (44%,51%)	303
Good (4-5)	40% (36%,42%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	46%
Very Poor vs. Good	Yes	51%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	53% (37%,58%)	109
Poor (2-3)	50% (45%,54%)	173
Fair (3-4)	43% (42%,47%)	291
Good (4-5)	45% (42%,46%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	76% (69%,77%)	56
Poor (2-3)	59% (51%,64%)	115
Fair (3-4)	45% (41%,51%)	110
Good (4-5)	17% (12%,22%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	45%
Very Poor vs. Good	Yes	52%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	68% (56%,73%)	39
Poor (2-3)	48% (38%,54%)	66
Fair (3-4)	54% (42%,60%)	92
Good (4-5)	45% (37%,49%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	51%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	27% (18%,36%)	80
Poor (2-3)	38% (35%,49%)	74
Fair (3-4)	47% (43%,51%)	68
Good (4-5)	47% (42%,49%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	16% (4%,26%)	31
Poor (2-3)	30% (28%,36%)	40
Fair (3-4)	41% (37%,47%)	95
Good (4-5)	45% (42%,47%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	44% (36%,49%)	44
Poor (2-3)	62% (53%,66%)	110
Fair (3-4)	46% (40%,52%)	125
Good (4-5)	33% (29%,39%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	46%
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	37% (20%,53%)	39
Poor (2-3)	61% (50%,65%)	67
Fair (3-4)	42% (37%,45%)	104
Good (4-5)	41% (36%,46%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	42%
Very Poor vs. Good	No	NA

Table A-21 Statewide and Physiographic Eco-region Analysis for Cropland Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	30% (22%,37%)	182
Poor (2-3)	32% (28%,40%)	300
Fair (3-4)	35% (31%,41%)	306
Good (4-5)	27% (24%,30%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	27% (19%,39%)	110
Poor (2-3)	32% (25%,42%)	173
Fair (3-4)	29% (27%,31%)	291
Good (4-5)	33% (29%,36%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	41% (36%,49%)	57
Poor (2-3)	26% (25%,31%)	115
Fair (3-4)	23% (18%,29%)	110
Good (4-5)	18% (16%,20%)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	25%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	39% (32%,46%)	39
Poor (2-3)	30% (23%,38%)	66
Fair (3-4)	26% (22%,28%)	92
Good (4-5)	19% (17%,22%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	28%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8% (6%,9%)	80
Poor (2-3)	14% (12%,21%)	74
Fair (3-4)	16% (14%,22%)	69
Good (4-5)	22% (21%,24%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8% (1%,19%)	31
Poor (2-3)	6% (5%,10%)	40
Fair (3-4)	20% (15%,22%)	95
Good (4-5)	21% (17%,22%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	35% (19%,43%)	45
Poor (2-3)	51% (45%,55%)	111
Fair (3-4)	52% (49%,56%)	127
Good (4-5)	37% (34%,40%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	12% (5%,42%)	40
Poor (2-3)	46% (35%,54%)	67
Fair (3-4)	51% (49%,55%)	104
Good (4-5)	50% (40%,52%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-22 Statewide and Physiographic Eco-region Analysis for Cropland Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	25% (19%,30%)	180
Poor (2-3)	24% (20%,26%)	299
Fair (3-4)	24% (21%,27%)	303
Good (4-5)	14% (12%,17%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	24%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	25% (15%,32%)	109
Poor (2-3)	25% (21%,30%)	173
Fair (3-4)	20% (18%,23%)	291
Good (4-5)	18% (15%,21%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	43% (30%,49%)	56
Poor (2-3)	17% (15%,25%)	115
Fair (3-4)	19% (16%,22%)	110
Good (4-5)	10% (8%,14%)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	18%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	41% (27%,46%)	39
Poor (2-3)	28% (20%,35%)	66
Fair (3-4)	17% (15%,21%)	92
Good (4-5)	14% (11%,16%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	22%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	2% (2%,3%)	80
Poor (2-3)	8% (6%,10%)	74
Fair (3-4)	10% (9%,11%)	68
Good (4-5)	11% (9%,12%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,2%)	31
Poor (2-3)	3% (3%,6%)	40
Fair (3-4)	10% (8%,11%)	95
Good (4-5)	11% (10%,12%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	30% (5%,40%)	44
Poor (2-3)	31% (27%,36%)	110
Fair (3-4)	30% (27%,33%)	125
Good (4-5)	22% (15%,24%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	17% (3%,27%)	39
Poor (2-3)	29% (25%,46%)	67
Fair (3-4)	28% (23%,31%)	104
Good (4-5)	26% (23%,30%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-23 Statewide and Physiographic Eco-region Analysis for Pasture/Hay Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	34% (32%,38%)	182
Poor (2-3)	38% (37%,41%)	300
Fair (3-4)	39% (36%,43%)	306
Good (4-5)	38% (35%,39%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	26% (20%,36%)	110
Poor (2-3)	33% (30%,38%)	173
Fair (3-4)	37% (33%,38%)	291
Good (4-5)	40% (38%,44%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	51% (39%,59%)	57
Poor (2-3)	45% (39%,54%)	115
Fair (3-4)	34% (30%,39%)	110
Good (4-5)	7% (5%,10%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	34%
Very Poor vs. Good	Yes	40%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	32% (20%,52%)	39
Poor (2-3)	32% (27%,38%)	66
Fair (3-4)	37% (33%,50%)	92
Good (4-5)	43% (32%,47%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	33% (20%,35%)	80
Poor (2-3)	40% (35%,42%)	74
Fair (3-4)	50% (49%,52%)	69
Good (4-5)	47% (45%,50%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	17% (6%,29%)	31
Poor (2-3)	33% (30%,47%)	40
Fair (3-4)	44% (38%,48%)	95
Good (4-5)	47% (43%,49%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	22% (17%,23%)	45
Poor (2-3)	32% (29%,36%)	111
Fair (3-4)	33% (24%,38%)	127
Good (4-5)	28% (26%,31%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	27% (14%,36%)	40
Poor (2-3)	32% (25%,39%)	67
Fair (3-4)	28% (26%,29%)	104
Good (4-5)	25% (24%,28%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-24 Statewide and Physiographic Eco-region Analysis for Pasture/Hay Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	39% (31%,43%)	180
Poor (2-3)	36% (32%,45%)	299
Fair (3-4)	31% (29%,35%)	303
Good (4-5)	27% (26%,30%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	33%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	21% (17%,27%)	109
Poor (2-3)	27% (25%,32%)	173
Fair (3-4)	31% (29%,35%)	291
Good (4-5)	32% (30%,35%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	54% (43%,63%)	56
Poor (2-3)	46% (39%,51%)	115
Fair (3-4)	31% (25%,36%)	110
Good (4-5)	6% (3%,9%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	31%
Very Poor vs. Good	Yes	38%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	33% (19%,45%)	39
Poor (2-3)	27% (20%,34%)	66
Fair (3-4)	40% (31%,49%)	92
Good (4-5)	35% (25%,37%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	25% (17%,32%)	80
Poor (2-3)	31% (27%,36%)	74
Fair (3-4)	40% (37%,41%)	68
Good (4-5)	38% (35%,41%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	16% (4%,24%)	31
Poor (2-3)	28% (25%,34%)	40
Fair (3-4)	33% (28%,37%)	95
Good (4-5)	38% (35%,40%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	24% (14%,29%)	44
Poor (2-3)	32% (30%,35%)	110
Fair (3-4)	21% (16%,24%)	125
Good (4-5)	17% (15%,19%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	21%
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	18% (9%,26%)	39
Poor (2-3)	27% (17%,32%)	67
Fair (3-4)	20% (15%,26%)	104
Good (4-5)	19% (16%,20%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-25 Statewide and Physiographic Eco-region Analysis for Barren Land Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,2%)	182
Poor (2-3)	1% (1%,1%)	300
Fair (3-4)	1% (1%,1%)	306
Good (4-5)	1% (1%,2%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,1%)	110
Poor (2-3)	1% (1%,2%)	173
Fair (3-4)	1% (1%,1%)	291
Good (4-5)	1% (1%,1%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	2% (1%,2%)	57
Poor (2-3)	1% (1%,1%)	115
Fair (3-4)	1% (1%,1%)	110
Good (4-5)	0% (0%,1%)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	1%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,2%)	39
Poor (2-3)	1% (0%,1%)	66
Fair (3-4)	1% (1%,1%)	92
Good (4-5)	1% (1%,1%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	1%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,1%)	80
Poor (2-3)	1% (1%,1%)	74
Fair (3-4)	1% (1%,2%)	69
Good (4-5)	1% (1%,2%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0% (0%,0%)	31
Poor (2-3)	2% (1%,3%)	40
Fair (3-4)	1% (1%,2%)	95
Good (4-5)	1% (1%,1%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,1%)	45
Poor (2-3)	1% (1%,1%)	111
Fair (3-4)	1% (1%,1%)	127
Good (4-5)	2% (2%,2%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,2%)	40
Poor (2-3)	2% (1%,3%)	67
Fair (3-4)	1% (1%,2%)	104
Good (4-5)	1% (1%,2%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-26 Statewide and Physiographic Eco-region Analysis for Barren Land Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,1%)	180
Poor (2-3)	1% (1%,1%)	299
Fair (3-4)	1% (1%,1%)	303
Good (4-5)	1% (1%,1%)	325
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,1%)	109
Poor (2-3)	1% (0%,1%)	173
Fair (3-4)	1% (1%,1%)	291
Good (4-5)	1% (1%,1%)	318
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (1%,2%)	56
Poor (2-3)	1% (1%,1%)	115
Fair (3-4)	1% (1%,1%)	110
Good (4-5)	0% (0%,0%)	86
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	1%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,2%)	39
Poor (2-3)	0% (0%,1%)	66
Fair (3-4)	1% (1%,1%)	92
Good (4-5)	1% (1%,1%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,1%)	80
Poor (2-3)	0% (0%,1%)	74
Fair (3-4)	1% (0%,1%)	68
Good (4-5)	1% (1%,2%)	115
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	0% (0%,0%)	31
Poor (2-3)	1% (0%,2%)	40
Fair (3-4)	1% (0%,1%)	95
Good (4-5)	1% (0%,1%)	112
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,1%)	44
Poor (2-3)	1% (0%,1%)	110
Fair (3-4)	1% (1%,1%)	125
Good (4-5)	1% (1%,1%)	124
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,1%)	39
Poor (2-3)	1% (1%,2%)	67
Fair (3-4)	1% (1%,1%)	104
Good (4-5)	1% (1%,1%)	104
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Table A-27 Statewide and Physiographic Eco-region Analysis for Forest Land Use in Watershed

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	4% (2%,5%)	182
Poor (2-3)	9% (8%,11%)	300
Fair (3-4)	17% (15%,19%)	306
Good (4-5)	24% (23%,24%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	17%
Very Poor vs. Good	Yes	13%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	4% (2%,6%)	110
Poor (2-3)	6% (4%,9%)	173
Fair (3-4)	15% (13%,17%)	291
Good (4-5)	20% (18%,21%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	11%
Very Poor vs. Good	Yes	10%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8% (6%,11%)	57
Poor (2-3)	13% (13%,17%)	115
Fair (3-4)	28% (25%,35%)	110
Good (4-5)	56% (50%,65%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	28%
Very Poor vs. Good	Yes	21%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	13% (9%,19%)	39
Poor (2-3)	14% (7%,21%)	66
Fair (3-4)	17% (13%,19%)	92
Good (4-5)	22% (18%,26%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	No	NA

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	2% (1%,4%)	80
Poor (2-3)	4% (2%,8%)	74
Fair (3-4)	14% (14%,16%)	69
Good (4-5)	22% (17%,22%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	14%
Very Poor vs. Good	Yes	9%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,2%)	31
Poor (2-3)	2% (2%,4%)	40
Fair (3-4)	14% (12%,16%)	95
Good (4-5)	20% (15%,21%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	8%
Very Poor vs. Good	Yes	8%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	4% (2%,11%)	45
Poor (2-3)	8% (7%,12%)	111
Fair (3-4)	18% (14%,20%)	127
Good (4-5)	24% (22%,27%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	18%
Very Poor vs. Good	Yes	13%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	8% (5%,16%)	40
Poor (2-3)	6% (2%,13%)	67
Fair (3-4)	17% (15%,19%)	104
Good (4-5)	20% (18%,22%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	14%
Very Poor vs. Good	Yes	11%

Table A-28 Statewide and Physiographic Eco-region Analysis for Forest Land Use in 60 m Buffer

Statewide Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	3% (2%,6%)	180
Poor (2-3)	10% (7%,16%)	299
Fair (3-4)	34% (30%,36%)	303
Good (4-5)	45% (41%,47%)	325
Group	Significant	Target Value
Poor vs. Fair	Yes	34%
Very Poor vs. Good	Yes	22%

Statewide Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	5% (3%,12%)	109
Poor (2-3)	6% (2%,12%)	173
Fair (3-4)	27% (24%,30%)	291
Good (4-5)	36% (34%,39%)	318
Group	Significant	Target Value
Poor vs. Fair	Yes	18%
Very Poor vs. Good	Yes	17%

Highland Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	9% (3%,12%)	56
Poor (2-3)	20% (19%,22%)	115
Fair (3-4)	37% (33%,42%)	110
Good (4-5)	64% (60%,70%)	86
Group	Significant	Target Value
Poor vs. Fair	Yes	37%
Very Poor vs. Good	Yes	28%

Highland Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	19% (12%,24%)	39
Poor (2-3)	15% (12%,20%)	66
Fair (3-4)	22% (15%,27%)	92
Good (4-5)	37% (35%,41%)	102
Group	Significant	Target Value
Poor vs. Fair	No	NA
Very Poor vs. Good	Yes	19%

Eastern Piedmont Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	2% (1%,4%)	80
Poor (2-3)	3% (0%,9%)	74
Fair (3-4)	36% (33%,40%)	68
Good (4-5)	38% (34%,44%)	115
Group	Significant	Target Value
Poor vs. Fair	Yes	36%
Very Poor vs. Good	Yes	19%

Eastern Piedmont Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	1% (0%,3%)	31
Poor (2-3)	3% (2%,9%)	40
Fair (3-4)	26% (23%,31%)	95
Good (4-5)	37% (33%,43%)	112
Group	Significant	Target Value
Poor vs. Fair	Yes	16%
Very Poor vs. Good	Yes	14%

Coastal Plain Benthic		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	3% (0%,9%)	44
Poor (2-3)	8% (5%,16%)	110
Fair (3-4)	30% (25%,34%)	125
Good (4-5)	45% (41%,53%)	124
Group	Significant	Target Value
Poor vs. Fair	Yes	30%
Very Poor vs. Good	Yes	19%

Coastal Plain Fish		
Biological Condition	90th Percentile (80% CI)	Number of Sites
Very Poor (1-2)	12% (7%,27%)	39
Poor (2-3)	3% (2%,16%)	67
Fair (3-4)	33% (31%,40%)	104
Good (4-5)	36% (31%,42%)	104
Group	Significant	Target Value
Poor vs. Fair	Yes	23%
Very Poor vs. Good	Yes	18%

Appendix B: General Causal Scenario Models

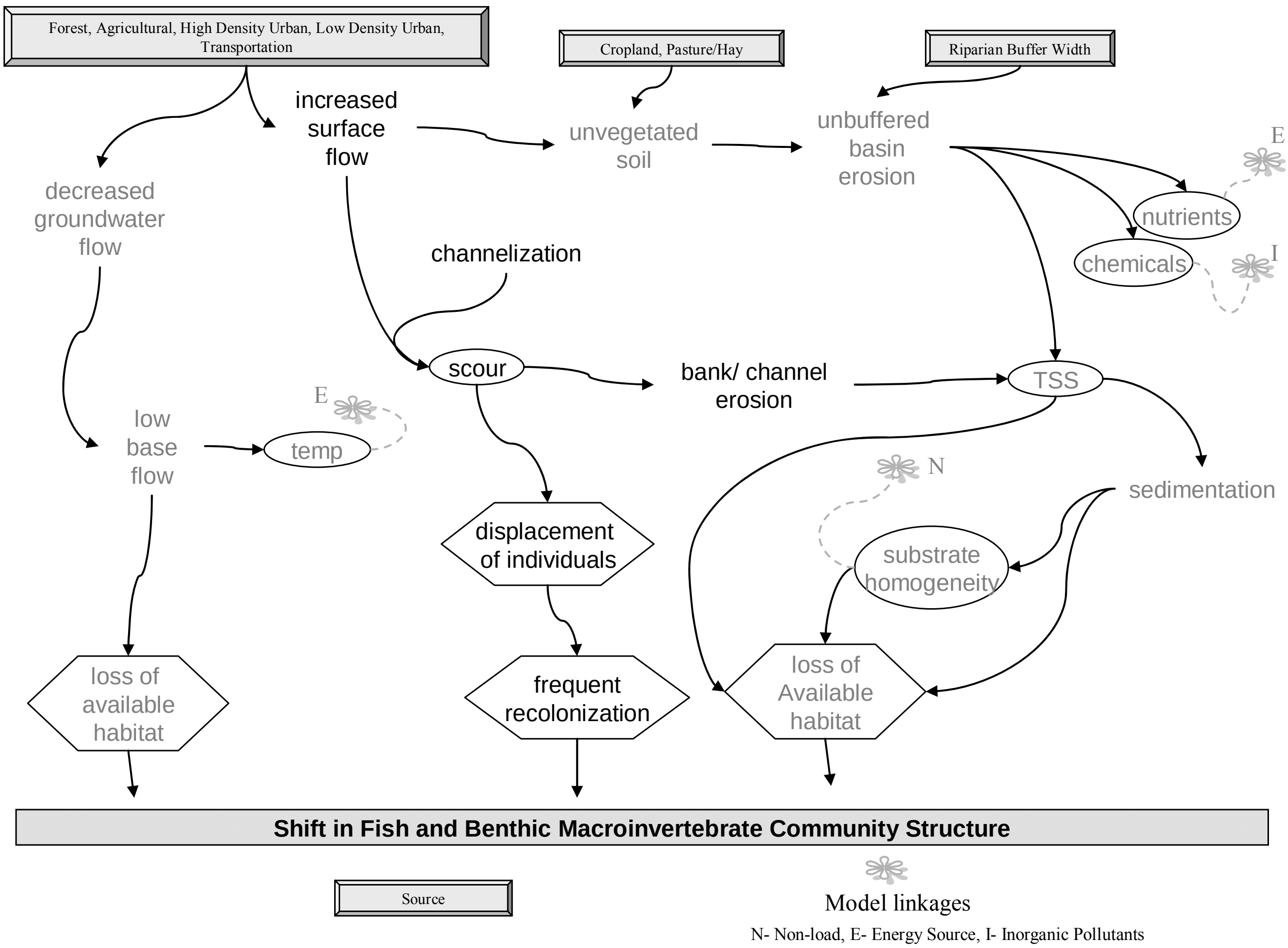

Figure B-1 Flow/Sediment Causal Scenario

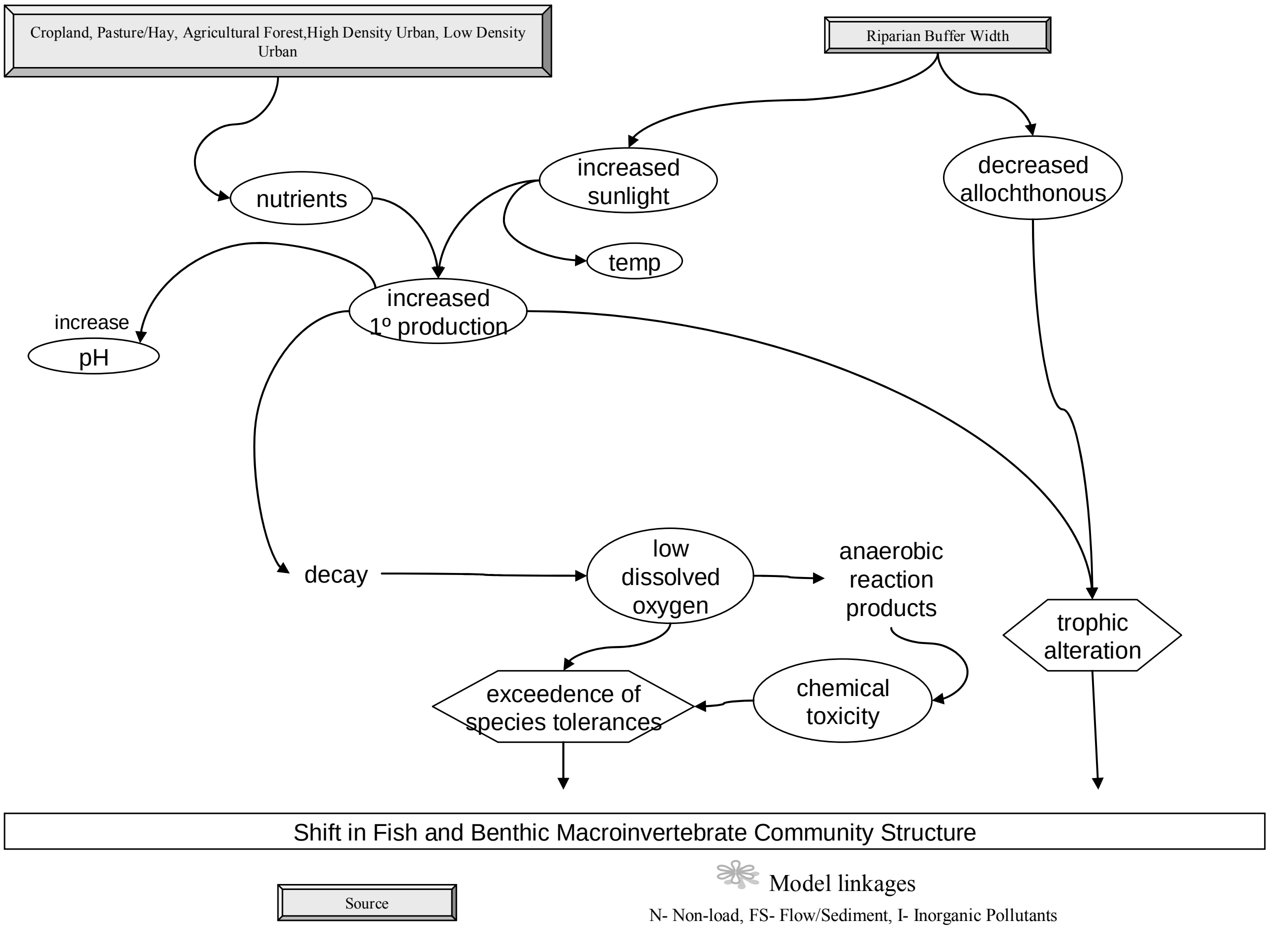

Figure B-2 Energy Source Causal Scenario

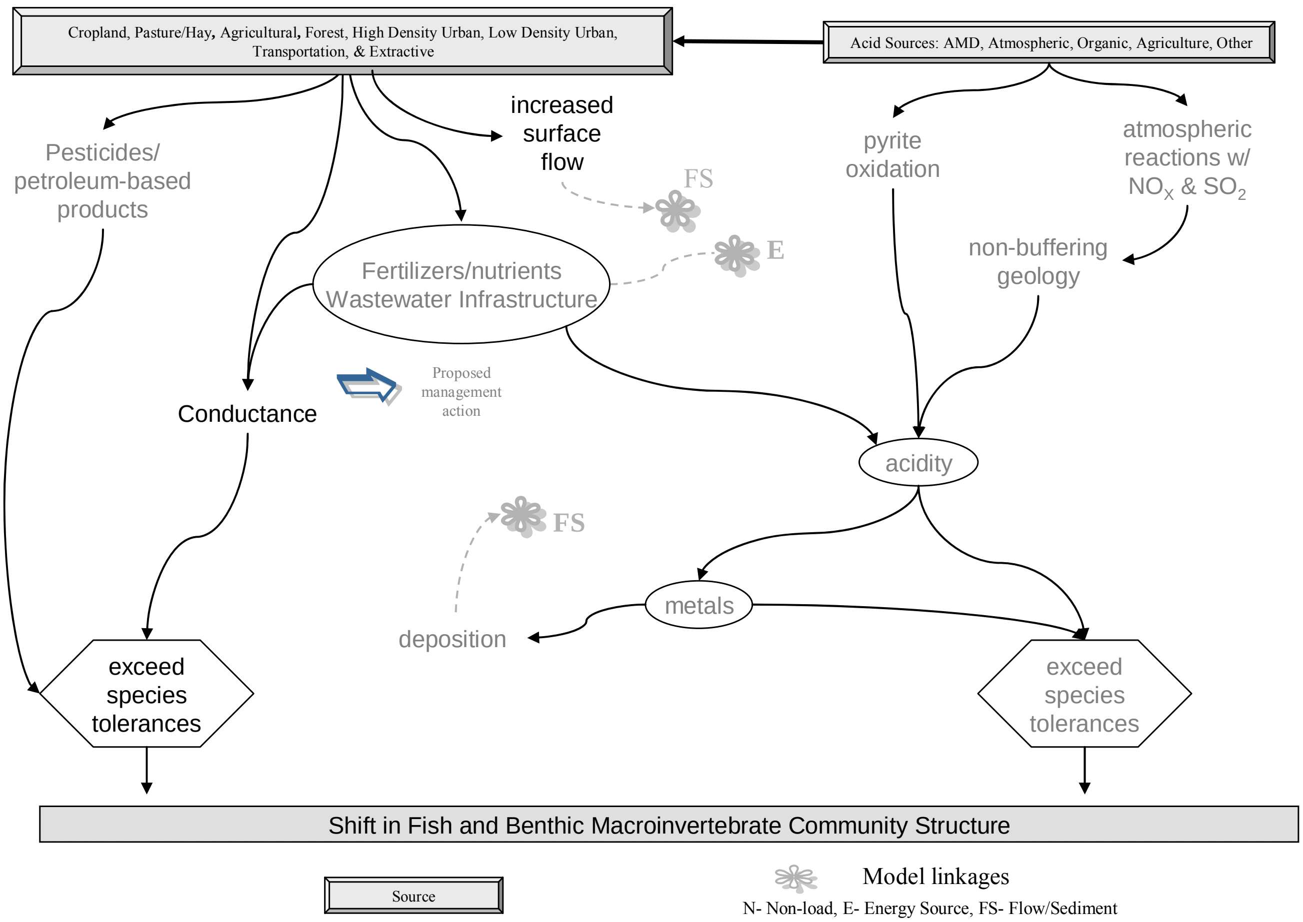

Figure B-3 Inorganic Pollutant Causal Scenario

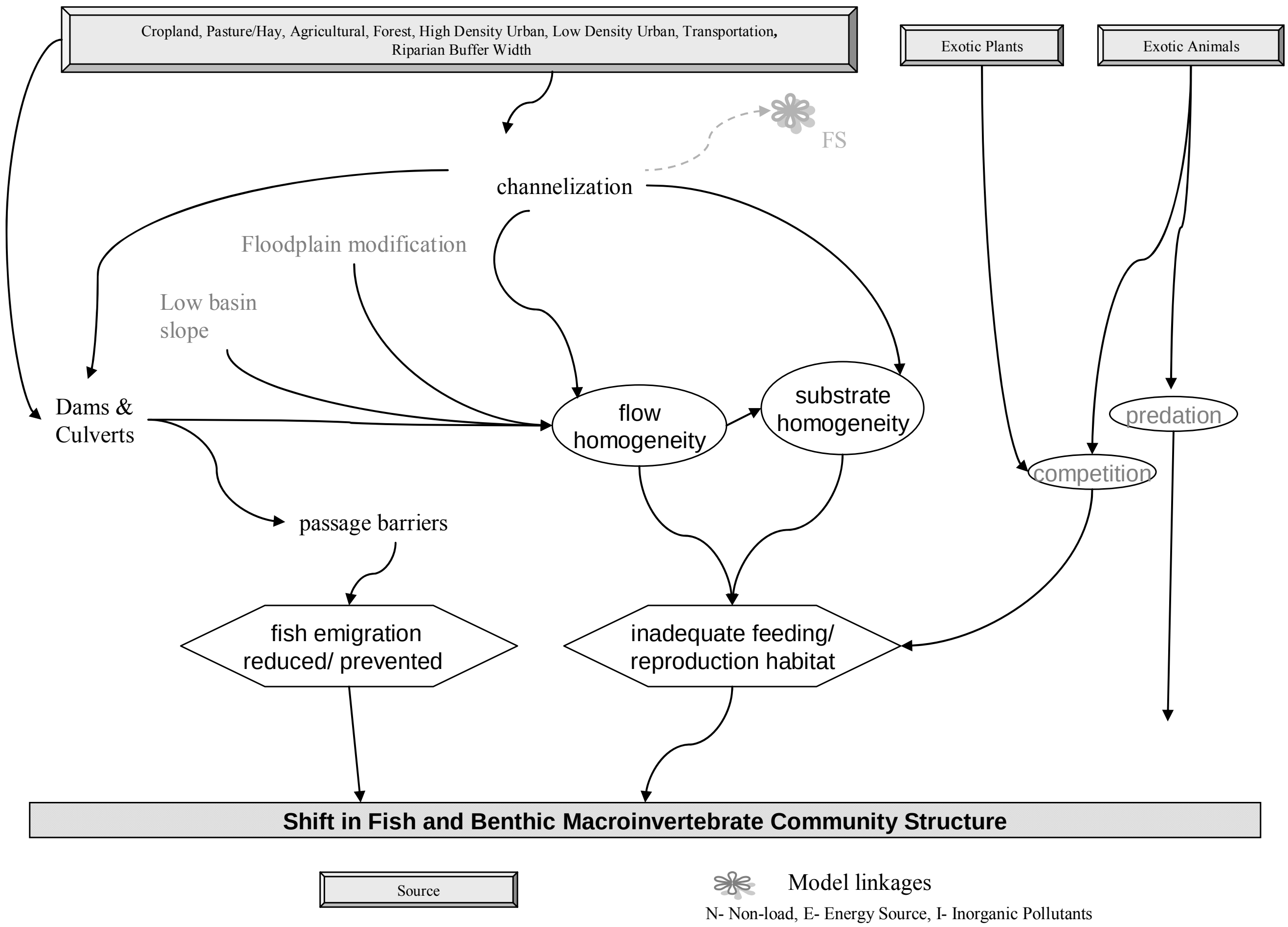

Figure B-4 Non-Load Causal Scenario